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Effects of Carbon to Nitrogen ratio on vermicomposting of Rice husk and Cow dung with fresh Biosolid

By

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Declaration

This is to certify that this thesis entitled "Effects of Carbon to Nitrogen ratio on vermicomposting of Rice husk and Cow dung with fresh Biosolid." submitted in partial fulfillment of the requirements for the award of the degree of M.Sc., in Tropical Land Resource Management to the School of Graduate Studies, Mekelle University, through the Department of Land Resource Management and Environmental Protection, done by Mr. Hailu Kendie Addis, Id.No. FDA/PS0030/98 is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

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Abstract

Vermicomposting is the process of turning organic debris into worm castings. Although earthworms have been found to improve the chemical properties of the vermicompost, there has not received due attention of the investigators in Ethiopia. This study was conducted for 70 days with objectives: to determine the effects of variation of C/N ratio on chemical properties of vermicompost; and earthworm biomass. The experiment was arranged in completely randomized design with three replications. The predetermined treatment, C/N ratio of the substrate were 15:1, 25:1, 35:1, 45:1, and 55:1 with and without earthworm. The 15 sample bins were incubated with 60 adult Eisenia foetida earthworms per each bin for the purpose of vermicomposting and a total of 1800 worms were used. The experiment was performed in worm bin of 10-liter capacity. The bins were initially filled to a 2 cm height with about 12 mm in size chips of stone, which was then covered with 2 cm thick layer of 1 – 4 mm size gravel to ensure proper air and water circulation. The bins were kept under shade and maintained at moisture content of 70% to ensure the optimum functioning of earthworms. The samples were analyzed to determine which methods most successfully produce highly usable materials. The results of this experiment revealed that addition of earthworm on the substrata at C/N ratio of 25:1 had significantly ($P < 0.05$) increased contents of available Phosphorus, Potassium, Organic carbon and creates favorable condition for earthworm to survive and reproduce since in these bin there was the highest biomass production as compared to some of the treatments and also relatively neutral of pH.

Key words: Biosolid, Compost, Cow Dung, *Eisenia foetida*, Rice Husk, Vermicomposting, Worm Cast.

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Acronyms

ANRS------------------------------Amhara National Regional State

ATVET ---------------------------Agricultural Technical and Vocational Education Training

EGS--------------------------------Employment Generation Schemes

LLPPA----------------------------Local Level Participatory Approaches

ILRI------------------------------- International Livestock Research Institute

PAs--------------------------------Peasant Associations

SAS------------------------------- Statistical analysis system

w----------------------------------with earthworm

wo---------------------------------without earthworm

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Chapter 1: Introduction

1.1 Background

The plough is one of the most ancient and most valuable of man's inventions; but long before man existed the land was in fact regularly ploughed, and still continues to be thus ploughed, by earthworms. It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have earthworms (Darwin, 1881).

Generally, in Ethiopia, the crop yield per year is expected to decline by one to three percent, while the population is growing at the rate of 3.3%. Therefore, this scenario implies the challenge of feeding the present and the future population on one hand while ensuring sustainable land management on the other hand. Sustainable land resource management requires rethinking of the roles of researcher, extension, land user, decision-makers and different stakeholders. Successful soil and water conservation interventions as part of integrated natural resource use to achieve sustainable land management need to manage communication at different levels. Particularly important is the communication at the farmer-extension and farmer-researcher interface along the anticipated impact pathways, right from the beginning of the intervention. Researchers engaged in integrated resource management assume the responsibility to ensure the appropriate communication media for different clients and partners (Mitiku *et al.*, 2006).

In the context of productivity, land degradation results from a mismatch between land quality and land use. Mechanisms that initiate land degradation include physical, chemical, and biological processes. Important among physical processes are a decline in soil structure leading to crusting, compaction, erosion, desertification, anaerobism, environmental pollution, and unsustainable use of natural resources (Lal, 1998).

Significant chemical soil degradative processes include acidification, leaching, salinization, decrease in cation retention capacity, and fertility depletion. Biological soil degradative processes include reduction in total and biomass carbon, and decline in land biodiversity. Soil structure is the important property that affects all the degradative processes. Thus, vermicompost which is a crucial component to stabilize the soil structure of an area could be a solution to decrease land degradation.

Vermicomposting is one way of enriching the soil physicochemical properties. It is simply composting with earthworms. Earthworms speed up the composting process, aerate the organic material in the bin, and enhance the finished compost with nutrients and enzymes from their digestive tracts. The best kinds of earthworms to use are red worms, also known as "red wigglers" and "manure worms". These worms thrive in decomposing organic matter such as rice husks, leaf piles; compost heaps, old manure piles, biosolids etc.

Researchers have identified and named more than 4400 distinct species of earthworm, each with unique physical and behavioral characteristics that distinguish them one from the other. These species have been grouped into three categories, endogeic, anecic and epigeic, descriptive of the area of the natural soil environment in which they are found and defined to some degree by environmental requirements and behaviors (Bouche, 1977).

Anecic species, represented by the common nightcrawler (*Lumbricus terrestris*), build permanent vertical burrows that extend through the upper mineral soil layer, which can be as deep as 4-6 feet. These species coat their burrows with mucous that hardens to prevent collapse of the burrow, providing them a home to which they will always return and are able to reliably identify, even when surrounded by other worm burrows. When deprived of this burrow environment anecic worms will neither breed nor grow. Anecic worms feed in decaying organic matter and are responsible for cycling huge volumes of organic surface debris into humus.

Endogeic species build extensive, largely horizontal burrow systems through all layers of the upper mineral soil. These worms rarely come to the surface, spending their lives deep in the soil where they feed on decayed organic matter and mineral soil particles. While most people believe all worms eat soil, it is only the epigeic species that actually feed on significant volumes of soil itself.

Earthworms are nature's clean-up crew, aiding in the production of lush, humus-rich topsoil from spent plant and animal materials. These elegantly efficient organisms have been on earth for hundreds of thousands of years longer than humankind, largely untouched by evolution due to their nearly perfect adaptation to their role in nature (Darwin, 1881).

The concept of vermicomposting started from the knowledge that certain species of earthworms consume a wide range of organic residues very rapidly, converting them into vermicompost, a humus-like, soil building substance in short time. The effective use of the earthworms in organic waste management requires a detailed understanding of the effect of the physicochemical properties of the substrate.

The role of organic carbon and inorganic nitrogen for cell synthesis, growth, and metabolism is important in all living organisms. To provide proper nutrition for earthworms during vermicomposting, carbon and nitrogen must be present in the substrates at the correct ratio. The usual practice is to arbitrarily add either a rich nitrogenous material, or a rich carbonaceous material to the feed substrate, depending on the situation, to correct for C/N imbalance. In addition, the conventional determination of C/N ratio is not always based on the proportion of each nutrient that is available for these processes, but on their absolute content in the substrate. More so, different earthworm species are impacted differently by C/N ratio and feed mixture type. Therefore, pilot studies are necessary to establish optimal C/N ratio for a specific earthworm species and a specific feed mixture.

Earthworm: a terrestrial annelid worm (class *Oligochaeta*); especially any of a family (*Lumbricidae*) of numerous widely distributed hermaphroditic worms that move through the soil by means of setae and feed on decaying organic matter. One important function of earthworms is to plow the soil by burrowing through it. These macro-pores provide the soil with passageways through which air and water can circulate. Without some kind of plowing, soil becomes compacted, air and water can't circulate in it, and plant roots can't penetrate it easily.

Introduction of earthworms to areas not previously populated has led to improvement of soil quality and productivity. Earthworm casts are sources of nutrients for plants. *Lumbricids* produced casts that contained 73 percent of the nitrogen found in a pasture soil from the ingested litter; indicating both the importance of earthworms in incorporating litter nitrogen into the soil and the inefficiency of nitrogen metabolism by earthworms (Syers *et al*., 1979). Earthworms increase the amount of nitrogen mineralized from organic matter in soil. Nitrogen-fixing bacteria are found in the gut of earthworms and in earthworm casts, and higher nitrogenase activity, meaning greater rates of N-fixation, are found in casts when compared with soil (Simek and Pizl, 1989). Nitrification is enhanced in earthworm casts, the ratio of nitrate-N to ammonium-N tends to increase when earthworms are present (Ruz Jerez *et al*., 1988).

Earthworms may increase levels of metabolic activity in soils, as measured by the amount of CO_2 evolved, yet nematode abundance and microbial biomass may decrease (Yeates, 1981; Ruz Jerez *et al*., 1988). This occurs because earthworms reduce the amount of substrate available to other decomposers, and because earthworms ingest other decomposer organisms as they feed. This process would tend to accelerate nutrient cycling rates. Some common agricultural *lumbricids* are *Allolobophora chlorotica,* the *Aporrectodea caliginosa* species complex (*A. trapezoides, A. turgida,* and *A. tuberculata),* and *L. terrestris.* Species common to organic rich habitats, such as *E. foetida* are rarely found (Lee, 1985).

1.2 Statement of the problem

Growing concerns relating to land degradation, the inappropriate use of inorganic fertilizers, atmospheric pollution, soil health, overgrazing, soil biodiversity and sanitation have rekindled global interest in organic recycling practices such as vermicomposting. The potential of vermicomposting to turn on-farm waste materials into a farm resource makes it an attractive proposition. Vermicomposting offers benefits such as enhanced soil fertility and soil health that engender increased agricultural productivity, improved soil biodiversity, reduce ecological risks and a better environment. However, many farmers, and especially those in developing countries find themselves at a disadvantage as they fail to make the best use of organic recycling opportunities using earthworm. Thus, vermicomposting could be one of the valuable options for Ethiopian farmers to restore or enhance their agricultural soil physical, chemical and biological properties.

1.3 Purpose of the study

In spite of a range of significance of vermicompost, the variation of same chemical properties of vermicompost caused by C/N ratio of the substrata used, being an important parameter has not received due attention of the investigators in Ethiopia.

In view of this gap in knowledge, this study is particularly carried out to evaluate the variation of effect of C/N ration on vermicomposting of rice husk and cow dung with fresh biosolids using (*Eisenia foetida*) earthworm.

1.4 General objective

The objective of this study is to use biosolids from a wastewater treatment plant in a vermicomposting process with and without *Eisenia foetida*.

1.4.1 Specific objective

Specifically, the focus of this study is to investigate and establish a suitable C/N ratio for vermicomposting of fresh biosolids amended with rice husk and cow dung, using *Eisenia foetida*.

1.5 Hypothesis

The C/N ratio of the substrates (Rice husk, Cow dung and Biosolid) does not significantly affect the chemical properties of vermicompost and compost at ($\alpha = 0.05$) probability significant level.

Chapter 2: Literature review

2.1 Basic Taxonomy

Earthworms are classified within the phylum *Annelida* and class *Oligochaeta* which consists of some 36 family's worldwide (Reynolds and Cook, 1993). Many of these families consist of aquatic or semi-aquatic worms, whereas the others are mostly or exclusively terrestrial forms. Twenty terrestrial families are recognized by Jameson (1988), and 23 by (Reynolds and Cook 1993). It is reported that there are 7254 species, both terrestrials and aquatic, in 739 genera (Edwards and Bohlen, 1996).

2.2 Earthworm Biology and Ecology

Earthworms are elongated, cylindrical segmented animals, ranging in length from a few millimeters to 1.4m, such as the giant Australian *Megascolides australis*. They consist of a relatively simple, tube-within-a-tube body plan, the internal tube comprising the alimentary canal. The body segments are separated by septa and are filed with coclomic fluid which provides a dynamic, hydrostatic "skeleton" for locomotion. Respiration occurs through the moist integument, where blood in subcuticular capillaries absorbs oxygen which is transported throughout the body in a closed vascular system driven by a series of muscular heart-like structures. Earthworms are hermaphroductive, each individual carrying male and female's reproductive organs. During reproduction, sperm is exchanged between two individuals and later released, along with eggs, into cocoons, secreted by the glandular cliteilum, a characteristic thickening along several anterior segments of sexually mature individuals. Further details of earthworm biology can be found in (Edwards and Bohlen 1996).

Earthworm occurs worldwide in most areas where water and temperatures are favorable for at least part of the year (all but desert and polar conditions). Across this rang of habitats, earthworms' display a wide array of morphological, physiological, and behavioral adaptations to environmental conditions. The abundance of earthworms across habitats is highly variable, depending on climatic and edaphic conditions, ecosystem type, and the degree to which the habitat has been altered, for example by agriculture. Under suitable conditions, soil C concentration has been shown to be highly correlated with earthworm population density and biomass (Edwards, 1983; Hendrix *et al.,* 1992). In additions, earthworm species can be classed in one of three morpho-ecological groupings that are Epigeic, Endogeic and Anecics (Bouche, 1977).

Epigeic species live in organic horizons and ingest large amounts of undecomposed litter. These species produce ephemeral burrows into the mineral soil for short periods only. They are relatively exposed to climatic fluctuations and predator pressures, and tend to be small with rapid generation times. A common example is *Eisenia foetida* (redworm, manure worm) which is used in vermicomposting (Bouche, 1977).

Endogeic species forage below the surface, ingest large quantities of soil with a preference towards organic rich soil, and build continuously ramifying burrows that are mostly horizontal. These species are apparently not of major importance in litter incorporation and decomposition since they feed on subsurface material. They are important in other soil formation processes including root decomposition, soil mixing, and aeration (Bouche, 1977).

Species which build permanent, vertical burrows that penetrate the soil deeply were termed Anecics by Bouche, (1977). These species are detritivores and come to the surface to feed on partially decomposed litter, manure, and other organic matter. The permanent burrows of Anecics create a microclimatic gradient, and the earthworms can be found shallow or deep in their burrows depending on the prevailing conditions. Anecics have profound effects on organic matter decomposition, nutrient cycling, and soil formation. The most common examples are *Lumbricus terrestris* and *Aporrectodea longa.*

2.3 <u>Benefits of Earthworms</u>

Deep burrowing species such as *L. terrestris* can burrow through compacted soil and penetrate plough pans, creating channels for drainage, aeration, and root growth (Joschko *et al*., 1989). Studies by Shipitalo and Protz (1989) elucidated some of the mechanisms by which earthworms enhance soil aggregation. Ingested aggregates are broken up in liquid slurry that mixes soil with organic material and binding agents. The defecated casts become stable after drying. Stewart *et al*. (1988) also presented evidence that earthworms initiate the formation of stable soil aggregates in land degraded by mining practice.

In forest ecosystems earthworms, especially litter feeders such as *L. terrestris*, can consume all the litter deposited on the soil surface within a period of several weeks (Knollenberg *et al*., 1985) or months (Satchell, 1967). Incorporation of litter by earthworms in apple orchards can be an important mechanism for preventing outbreaks of scab fungus, spores of which are transmitted from litter to new foliage by spring rains. Raw (1962) found a high correlation between *L. terrestris* biomass and apple leaf litter incorporation, with over 90 percent of litter incorporated during the winter when this species was abundant. Incorporation of surface litter may be an important function of earthworms in no-tillage agro-ecosystems.

Introduction of earthworms to areas not previously populated has led to improvement of soil quality and productivity in New Zealand grassland (Martin, 1977), on drained Dutch polders (Van Rhee, 1977), in heathland in Ireland (Curry and Bolger 1984), and in mining spoils in the U.S. (Vimmerstedt and Finney, 1973).

Earthworms can play a variety of important roles in agro-ecosystems. Their feeding and burrowing activities incorporate organic residues and amendments into the soil, enhancing decomposition, humus formation, nutrient cycling, and soil structural development (Mackay and Kladivko, 1985; Kladivko *et al*., 1986). Earthworm burrows persist as macropores which provide low resistance channels for root growth, water infiltration, and gas exchange (Kladivko and Timmenga, 1990; Zachmann and Linden, 1989). Quality, quantity and placement of organic matter is a main determinant of earthworm abundance and activity in agricultural soils (Edwards, 1983; Lofs-Holmin, 1983), as are disturbances of the soil by tillage, cultivation, and the use of pesticides (Doran and Werner, 1990).

2.4 Management Effects on Earthworms

Earthworms are not favored by tillage, and in general the greater the intensity and frequency of disturbance, the lower the population density or biomass of earthworms (Haukka, 1988; Mackay and Kladivko 1985; Edwards, 1983; Gerard and Hay, 1979; Barnes and Ellis, 1979). Agricultural soils are generally dominated by species adapted to disturbance, low organic matter content, and a lack of surface litter. Earthworms are dependent on moderate soil moisture content, and cultivation tends to have a negative effect on earthworms by decreasing soil moisture (Zicsi, 1983).

Earthworm populations are usually significantly depressed in cropped fields relative to pasture or undisturbed lands. Lumbricids in a South African soil were decreased by cultivation to about one-third of original levels. *Aporrectodea trapezoides* was less affected than *Eisenia rosea*, possibly because it is able to burrow more deeply in the soil and escape the zone of disturbance (Reinecke and Visser; 1980). Gerard and Hay (1979) reported 93 earthworms per square meter in normally plowed plots, including *A. caliginosa, A. chlorotica, A. longa,* and *L. terrestris.* Earthworm abundance increased in plots that received disk cultivation, or no-till treatment. Earthworm abundance doubled in no-till soybeans as compared with plowing (Mackay and Kladivko, 1985).

While a major function of tillage is to decrease bulk density of soil and increase porosity, it only increases micro-porosity. Macro-pores, which may be of physical or biological origin and which can play an important role in conducting water rapidly into the soil, are destroyed by tillage. For instance, a 67 percent decrease in the rate of infiltration after plowing a tropical forest soil was attributed to the destruction of earthworm burrows. Soil compaction caused by agricultural traffic can also decrease earthworm populations (Bostrom, 1986).

A study in Denmark found that 20 Kg m^{-2} of manure was optimal for increased earthworm abundance and biomass (Andersen, 1980). *L. terrestris, A. longa,* and *A. caliginosa* were increased by manure, while *A. rosea* and *A. chlorotica* were not influenced. The Rothamsted Experiment Station plots in England which received manure for 118 years also had increased earthworm abundance, and inorganic fertilizers in this case caused decreases in earthworm populations (Edwards and Lofty, 1974). Heavy applications of inorganic fertilizers may cause immediate reductions in earthworm abundance (Edwards, 1983).

Organic mulches enhance earthworm habitat by moderating microclimate and supplying a food source. In corn plots in Pennsylvania, earthworms were most abundant in the fall in treatments that were not plowed before winter and where corn residues had been chopped and left as a mulch, regardless of whether the plots were organically or conventionally managed (Werner and Dindal, 1990).

Effects of agricultural pesticides on earthworms depend on the chemical used. Herbicides tend to have low toxicity for earthworms, but can cause population reductions by decreasing organic matter input and cover from weed plants. Fungicides and fumigants tend to be very toxic to earthworms. Application methods may have unique effects on ecological groups of soil animals. For instance, the fungicide benomyl caused reductions of field populations of earthworms. Anecics such as *L. terrestris* were most susceptible to surface applications, and were less affected by incorporation of the pesticide into the soil.

Because *L. terrestris* forms permanent burrows, it does not come into contact with subsurface soil beyond its burrow. However; endogeic species such as *A. caliginosa,* which continuously extend their burrows as they feed in the subsurface soil, were most susceptible when benomyl was incorporated (Edwards and Brown, 1982).

2.5 Vermicomposting Materials

Earthworms can be fed all forms of food waste, yard and garden waste, paper and cardboard, etc. Yard wastes, such as leaves, grass clipping, straw, and non woody plant trimmings can be composted. Leaves are the dominant organic waste in most backyard compost piles. If grass clippings are used, it is advisable to mix them with other yard wastes; otherwise the clippings may compact and restrict airflow. Branches and twigs greater than ¼ inch in diameter should be put through a shredder/chipper. Kitchen wastes such as vegetable scraps, coffee grounds, and eggshells may also be added. Sawdust may be added in moderate amounts if additional nitrogen is applied. Approximately 1 kg of actual nitrogen is required for 100 kg of dry sawdust. Wood ashes act as a lime source and if used should only be added in small amounts (5 kg per ton of waste). Ordinary black and white newspaper can be composted; however, the nitrogen content is low and will consequently slow down the rate of decomposition. If paper is composted, it should not be more than 10% of the total weight of the material in the compost pile. What is more, there can be several names designated to vermicomposting. Basically all are same but vary only with extent of waste mass to vermicomposted and composting containers www.NIIR.org.

2.6 <u>Palatability of the Substrata to Earthworm</u>

Organic debris is more palatable to earthworms if it is fresh or incubated for up to 2 weeks. The particle size of organic matter does not matter. In Martin *et al.* (1992) it was shown that when fresh material is compared to incubated material, worms prefer fresh organic matter as in undecomposed plant debris or debris incubated for 2 weeks. Incubation of the material fed to earthworms for 2, 5 and 10 weeks caused an increase in growth rate and yield efficiency. With fresh plants (or plants incubated for 10 weeks or less) worms eat less and gain more weight than with material incubated for more than 10 weeks.

Martin *et al.* (1992) states that worms prefer leaves to roots: When leaves are incubated for more than 10 weeks however the material becomes only as beneficial as fresh root material: plant material decomposed for a long time has less nutritive value. When roots are incubated for 2-5 weeks they increase growth rate, but without a change in yield efficiency. This was explained by the fact that fresh OM has a higher water-soluble content and more N availability. Also in the same study all plant materials have the same value after a long incubation time since all easily assailable compounds are gone. When legumes and grass were compared they gave different yield efficiency results although they both have same N content because legumes have higher nitrogen assimilability. As to the particle size effect, a fraction of soil OM was replaced with labeled C - OM. The results showed that worms ingested similar amounts of coarse OM (young OM – 250 – 200 μm) and fine OM (0.20μm). This indicates that particle size does not matter (Martin *et al.,* 1992). Palatability of different types of litter to earthworms may also depend on nitrogen and carbohydrate content, and the presence of polyphenolics such as tannins

(Satchell, 1967). Earthworms prefer materials with a low C/N ratio, such as clovers, to grasses which have a higher C/N ratio (Ruz Jerez *et al*., 1988). Colonization of litter residues by microorganisms also increases palatability (Cortez *et al*., 1989), as does leaching of feeding inhibitors.

2.7 <u>Carbon and Nitrogen Requirements of Earthworms</u>

Although high amounts of low molecular weight proteins encourage microbial growth and consequently mineralization there is a possibility that earthworms have lower requirements than microbes in processing C and N (proteins included) since material that goes through the earthworm gut show a higher mineralization rate than in the case where it is just incorporated in the soil (where decomposition occurs through microbes); Devliegher and Verstraete (1996) studied the effects of nutrient enrichment processes (i.e. allowing the passage of organic residues from the surface of the soil to below the surface) and those of gut associated process (i.e. enzymatic activities in the earthworm gut that increase the nutrient content of the ingested residues). They concluded that if the weight-increase of the worms is accounted for, the nutrient content of ingested organic material largely makes up for the nutrient content of the same material when simply incorporated in the soil. Therefore we might assume that earthworms have less restriction than microbes on protein quality and carbon to protein ratio as related to decomposition of organic matter (Ndegwa and Thompson, 2000).

2.8 <u>Construction of Worm Bin</u>

Bins can made of wood or plastic, or from recycled containers like old barrels or trunks. They also can be located inside or outside the house, depending on your preferences and circumstances. As *Eisenia foetida* tend to be surface feeders, bins should be no more than 8 to 12 inches deep. Bedding and food wastes tend to pack down in deeper bins, forcing air out. Resulting anaerobic conditions can cause foul odors and death of the worms.

The length and width of the bin will depend on whether it is to be stationary or portable. It also depends on the amount of food waste produces. Wooden bins have the advantage that they are more absorbent and provide better insulation. Do not use redwood or other highly aromatic woods that may kill the worms. Plastic tends to keep the compost too moist. Plastic, however, tends to be less messy and easier to maintain. Be sure containers are well cleaned and have never stored pesticides or other chemicals. Drilling air/drainage holes (0.5 to 1 cm diameter) in the bottom and sides of the bin will ensure good water drainage and air circulation. Place the bin on bricks or wooden blocks in a tray to catch excess water that drains from the bin. The resulting compost tea can be used as a liquid fertilizer around the home landscape.

Each bin should have a cover to conserve moisture and exclude light. Worms prefer darkness. Bins can be covered with a straw mulch to ensure darkness while providing good air ventilation. Outdoor bins may require a lid to exclude scavengers and other unwanted pests.

Outdoor bins should be insulated from the cold to protect the worms. One option is to dig a rectangular hole 12 inches deep and line the sides with wooden planks. The bottomless box can then be filled with appropriate bedding material, food wastes, and worms. Food wastes can be continually added as they accumulate. The pile should be kept damp and dark for optimum worm activity. During the winter, soil can be piled against the edges of the bin and straw placed on top to protect the worms from cold weather. Do not add food waste to outdoor bins in the winter because this could expose the worms to freezing weather www.NIIR.org.

2.9 Enhancing Earthworm Populations

There are many creative ways in which a farmer can manage for earthworms. A first step might be to determine what earthworm ecotypes are present, and how abundant they are. Endogeic species are most commonly found. These are useful, but a mixed community including anecic species as well would be even more beneficial, especially for incorporation of surface matter. Direct inoculation is one possible method, but transferring blocks of soil (one cubic foot each) from an area with a large earthworm population into a farm soil might work better. It is also important to consider what species should be introduced, and this is where research specific to seasonally-dry climates in Ethiopia is needed. Much of our knowledge about earthworms concerns species of one family, the Lumbricidae, which are native to moist temperate areas of Europe. The spread of these earthworms has paralleled European colonialism around the world.

One management idea for introducing desired species is to set aside a small area of land on a farm to be managed exclusively as an earthworm reservoir. If needed, the soil could be limed to bring it near pH 7 and a cover crop established and cut periodically to provide organic mulch as food and physical cover. In this area a community of the desired species could be established and built up. From this reservoir blocks could periodically be taken and introduced into the field. Rate of spread would vary with species and conditions in the field. *Lumbricus terrestris* is capable of traveling at least 19 meters on the soil surface in the course of one evening foray (Mather and Christensen, 1988). This is a long term process for establishing earthworms, and would only be successful if ample organic matter was supplied to the soil where earthworms were being introduced, and if physical and chemical disturbances of the soil were minimized. Organically managed perennial crops would be ideal for this method.

2.10 Moisture Requirement

Vermicomposting has been successfully used for composting different types of wastes, such as municipal and industrial sludge (Edwards and Bohlen 1996), though optimal moisture and the best proportions of organic waste are required for an efficient vermicomposting. Although moisture requirements and preferences of *Eisenia foetida* are well known, the optimal conditions of vermicomposting depend on the type of substrates www.NIIR.org.

2.11 Effect of Ingestion by Earthworms

As feed passes through the earthworm gut the material is mineralized and plant nutrients are available. Many studies were conducted on the process by which earthworms transform organic matter after ingesting it and on the properties of the resulting material, but very few were based on stabilized casts, compared to synthetic fertilizers and compost. Orozco (1996) investigated the ability of *Eisenia foetida*, one of the most promising earthworms for vermicomposting, to enrich coffee pulp through digestion. Earthworms increase nitrogen mineralization rate (Pashanasi, 1992; Parmelee, 1988; Ruz-Jerez, 1992). Available N increased irrespective of the residues the earthworms feed on or the growth temperature, that was attributed to the increase in oxidized C due to soil ingestion, and not due to change in soil texture as the soil was not mixed (Ruz-Jerez, 1992). Binet (1992) found that the consumption of Rye grass by Earthworms to be about 2.4-mg dry weight g^{-1} fresh mass of earthworm day^{-1}, and 3 times more N was released in casts than in the soil before ingestion, which represents 0.13 mg N / g of live worm / day. Furthermore, a 10% N renewal in earthworm biomass in 85 days was observed, meaning 10% of worm-biomass N was replaced by N from the soil, and 28% of available N could be due to N excretion. Extractable carbon was found to increase in soil material ingested by earthworms, which was explained by the possible effect of indigenous enzymes in the gut and the incomplete resorbtion of organic C before excretion. The excreted polysaccharides in the earthworm gut (Daniel and Anderson, 1992) could also be responsible for this increase. According to (Lavelle 1992), high levels of ammonium are found in fresh casts due to the excretion of NH_4 through the endonephridia gland into the gut, and the mineralization of soil organic matter by the ingested soil microflora in the middle and posterior part of the gut. Low NO_3 in fresh casts shows that nitrate is not a metabolic product of earthworm (Lavelle, 1992).

2.12 Casts Structure

Casts have a structure that is similar to a slow release granule: it has an organic matter core and a clay casing. Chan & Heenan (1995) worm casts had a composite structure, made of units 210-500 μm in diameter which were made of smaller spherical subunits (50-100 μm). Casts were significantly more water stable and higher in total nitrogen than in soil aggregates of the same size. Porosity in the casts was created by spaces between the subunits, which were composed of very densely packed clay/silt size particles. When earthworms were added to soil made of 1-2 mm aggregates molding processes in the earthworm gut destabilized the soil structure but at the same time biochemical processes act as an antagonistic stabilizing system. Shipitalo (1987) observed that freshly deposited moist casts were 26 to 41% more dispersible than uningested moist soil due to disruption of some existing bonds during gut transit. When casts was aged or dried there were a stronger bond of microbial polysaccharides and other organic materials to clay, predominantly via clay-polyvalent cation-organic matter linkages involving calcium (Shipitalo, 1987). Zhang & Schrader (1993) showed that organic C and $CaCO_3$ act as bonding agents and the $CaCO_3$ is involved with binding linkages with organic matter during digestion, the more stable are the formed aggregates. They also observed that in *L. terrestris* casts was very water stable, may be due to the presence of Ca humate or organic matter-polyvalent cation-soil particle bonds. Water extractable polysaccharides increased too, may be due to enrichment of mucopolysaccharides during ingestion, or from cutaneous polysaccharides (Zhang & Schrader, 1993). In Marinissen & Dexter (1990) aging made casts more stable, probably due to fungi that developed on the surface of the 6 days old casts. Artificial casts were made by molding soil at 100% moisture and pushing it through a 1.5 mm opening syringe, and compared to natural casts for its stability, which was measured as the capacity to prevent clay dispersion. Internal stability was measure by breaking down casts (magnetic stirrer) and the external one by using a paddle stirrer. Stability of the aggregate surface increased with aging while the internal stability remained the same. Since internal stability seems to depend on % of microaggregates, no new ones were formed (Marinissen & Dexter, 1990). Shipitalo & Protz (1989) observed that earthworms fragmented litter by grazing and a liquefied soil and debris mixture formed in their gut. In the gizzard, more fragmentation, microbial activity and digestive enzymes decompose organic matter, which becomes part of the soil plasma. Lignified particles resist fragmentation and clay minerals are brought close to newly formed bonding agents (polysaccharides). The organic matter enriched plasma adheres to surfaces of the organic skeleton of resistant organic fragments (with the help of bonding material), forming new aggregates. Pellets are excreted in this state and both drying and aging strengthens the bond between organic and mineral components. Therefore, Shipitalo & Protz (1989) concluded that ingestion of soil and litter in earthworms brings clay in close contact with decomposing organic fragments, creating the organic matter cored microaggregates. Organic matter is encapsulated by clay therefore resist rapid decomposition. The linkages within the aggregates consist of clay-polyvalent cation - organic matter bonds and they seem to make aggregates more stable.

2.13 Salinity in Earthworm Casts

Salinity levels are moderate in casts, since passage through the earthworm gut does not increase the level of some salts (Ca, Mg, and Na). Casts seems to reduce the salinity problem caused by an excess of NH_4 in an experiment where tomato plants were grown in sand, clayey loam, and garden soil processed by earthworms. Feeding with NH_4 (instead of NO_3) slowed down plant growth in sand, less in loam, and not at all in soil processed by earthworms (Borowski, 1995). Exchangeable Ca, Mg and Na were marginally higher in casts than in non-ingested soil, and that ingestion by earthworms increased the potassium level of the soil www.wormdigest.org.

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2.14 Production of Earthworm Casts

As feed passes through the earthworm gut, the material is mineralized and plant nutrients are made available. Edwards (1995) explained that, earthworms ingest organic matter and egest to make it much finer after passing through the grinding gizzard. Worms feed on the microorganisms that grow on the organic material. They take over the role of aerating the materials that is necessary in traditional composting to maintain aerobic conditions and earthworm organic matter turnover rate is much higher than the traditional composting as they process 3 feet deep layers of suitable organic material in less than 30 days (Edwards, 1983). Edwards & Bates (1992) found that *Eisenia foetida* to be the best choice due to its wide temperature and moisture tolerance, and because it is a strong worm, easy to handle and it out competes other species. The highest growth rate in *Eisenia foetida* is at 30^{o}C and 85% moisture. A maximum of cocoons hatched at 20^{o}C, which is considered optimum growth temperature for this worm (Edwards & Bates, 1992). Worms die at temperatures higher than 35^{o}C, and they decomposed OM best at temperature between 15 and 25^{o}C, and moisture levels of 70 to 90%. Different materials are mixed before processing for faster results and a better product. Worms are also found to have a limited tolerance to some chemicals. The most commonly used earthworm is *Eisenia foetida* and the best results are obtained by using raised beds. Feedstock is added at the top and casts are collected at the bottom through mesh floors. In same 25 kinds of vegetables, fruits or ornamentals casts did better than compost or commercial potting mixes (Edwards, 1983). Furthermore, scientific evidence shows that human pathogens do not survive the vermicomposting process (Edwards and Bohlen, 1996).

2.15 Nutrient Dynamics in Compost and Earthworm Casts

Plant treated with sludge compost or biosolid may still show N deficiency, even when supplemental N-fertilizers are added. The N in sewage sludge is almost in organic forms and resistant to mineralization because the more easily mineralizable N has already released during sewage sludge processing. Application of large amount of sewage sludge compost is necessary as the mineralization rate of organic N raises between 10 to 40% on first year of application www.vermico.com. Therefore when applied at agronomic rates compost can support plant growth, in adequate amounts of supplemental N fertilizers are used (Sims, 1990). Composted urban refuses were studied as organic fertilizers by Villar *et al.*, (1993). Most of the total N was in organic forms; NH_4 was more abundant than NO_3, and calcium was the most abundant nutrient followed by K, Na, Mg and P. Most of the Ca and Na were in available forms; available K and Mg were lower and available P very small.

On the other hand, NH_4 levels are high in fresh earthworm casts but casts stabilize after 2 weeks of aging through nitrification. The pH level in casts is slightly low, which could reduce denitrification. In fresh casts, NH_4 levels were very high (294.2-233.98 $\mu g\ g^{-1}$ dry cast) due mineralization in the earthworm gut. During the first week of cast aging, NH_4 levels decreased while NO_3 levels increased, due to rapid nitrification in the fresh casts. After two weeks the levels of NH_4 and NO_3 were stabilized, probably due to organic matter protection in dry casts (Decaens, 1999). Casts tend to stabilize through nitrification after being deposited; in a garden soil processed by earthworm. Ammonium underwent complete nitrification compared with 33 and 9% nitrification in loam and sand, respectively (Borowski, 1995). According to (Decaens, 1999) C increased during cast aging (+100%), possibly because of CO_2 fixation or macro faunal activities in casts. Stabilized earthworm casts leached less dissolvable organic carbon than from undigested soil. Nutrient losses from casts that underwent several wetting / drying cycles show that there was a strong protection of nutrients in casts at first, but this was reduced as the aggregate structure was weakened (McInerney *et al*., 2000). After a 20 days long incubation of fresh casts a rapid increase in mineral N was observed during the first few days after deposition, and then a decrease to a level 4.5 times higher than in the soil. Also the NH_4 level was higher in fresh casts than in the control (Rangel, 1999). The decrease of mineral N in time in casts can be due to N becoming microbial biomass, volatilized, denitrified, or leached (Lavelle, 1992). In Haynes (1999) uningested soil and casts were incubated for 42 days, and extractable P levels were similar in casts and soils during the initial stages of incubation, but were larger in casts after 28 and 42 days. Activities of arylsulphatase and acid phosphates were lower in casts than in uningested soil; therefore the mineralization of organic matter during gut transit could be the reason for the increase in extractable P and S during incubation. Haynes (1999) concluded that mineral N increases because of mineralization in the gut, but P and S levels increase due to mineralization after egestion. In Lavelle (1992) mineral N in casts was mostly in the form of ammonium, and after a 26 days long incubation NH_4 was nitrified or immobilized in biomass. The incubation of soil before ingestion increased NH_4 production in casts and being slightly acidic casts do not favor the denitrification of NO_3. Biomass N was stable (relatively) after an initial flush on day 1.

2.16 Earthworm Casts for Plant Growth and Health

Presence of worms increases plant growth and N uptake as opposed to unfertilized soil. In the 1980's, at a research station in Rothamsted, earthworms were collected and put in buckets of clean water, in batches of 250. A solution of 0.2% formaldehyde was spread on the field to drive the worms out of their burrows. They were then rinsed in a second bucket of clean water and spread at a rate of 250 worm's m^{-2} over a landfill site capped with 15cm of clay subsoil, treated with domestic dried sewage solid at 1 kg m^{-2} and planted with grass. A higher plant growth was observed in the presence of worms (Edwards & Bates, 1992). Earthworm casts were found to increase nutrient uptake in Tomati (1994), including nitrogen and several ions, particularly Mg and K. When used in horticulture, earthworm casts have a hormone-like effect. The biological effect of casts is linked to microbial metabolites that influence plant metabolism, growth and development (Tomati *et al*., 1997). Root biomass was slightly lower in the earthworms than in the bare soil treatment and N content of leaves was twice higher in the treatment with earthworms. This was only partially explained by earthworm mortality. N uptake increases in the presence of earthworms and is correlated ($r = 0.85$) with the increase in CO_2 production (Ruz – Jerez, 1992). Casts increase plant dry weight and N, P, Mg and K uptake from the soil. The application of earthworm casts (0, 100, and 300 g per 3.5 kg soil) increased the dry weight of soybean by 40 to 70%. The nitrogen absorbed by the plants from the soil increased to 30 to 50%. Phosphorous and potassium in the plant were twice that of the control. The amount of organic matter, total nitrogen, phosphorous and potassium in the soil also increased, as well as available phosphorous and potassium in the soil (Lui *et al*., 1991).

A recent study found that earthworm produced vermicompost dramatically increases germination and growth in many plants. Adding only 5% of the vermicompost to commercial growing media (95%) significantly increased plant growth (Edwards, 1993). Many species of earthworms actually eat the bad microbes (fungi, bacteria, etc.) that are plant pathogens and in the process they also increase the good beneficial microbes. It has recently been discovered that in feeding, earthworms consume spores of mycorrhizae, a beneficial fungi that help roots take up nutrients. Studies in New Zealand found that earthworms at least doubled yields in all cases and adding worms to crops has become standard agricultural practice. Experiments at Tennessee Technological University found that 10% vermicompost in a potting mix improved the germination of seeds of low viability (*Echinacea purpurea*) by 43%. Researchers at Ogun State University have found that a tea made from the worm castings speeds up the sprouting of hard to germinate seeds following a 1 hour soaking.

2.17 <u>Sensitivity of Earthworm to Pesticides, High Salinity and Alkalinity</u>

A pH of 8.5 and electrical conductivity of 8 dS m-1 were found to harm earthworms. Alklainity and salinity are harmful to both earthworms and microorganism (Santamaria-Romero *et al*., 2001). Worms can be used to assess the environmental effects of chemicals because they can predict the effect of chemicals on other soil invertebrates. The survival rate of earthworms when a toxic chemical is added to the soil would then be the indicator of the level of toxicity of these chemical (Edwards *et al.* 1992).

Edwards *et al.* (1992) state that pesticides tested on worms in labs are more consistent since a standard number of worms from the same species are in intimate contact with the pesticides. Still soils with different absorbing capacities have been used. He also considers that the invalid methods would be applying a chemical directly to the earthworms (the results would be unrealistic), mixing a chemical with the earthworm food (due to food repellency problems) and injecting the tested chemical into the earthworm, since this can cause direct injury and falsify the results.

Chapter 3: Materials and Methods

3.1 Instrumentation

A worm bin which had a capacity of 10-liter in volume was used. Then the small sized stone, bedding material such as compost and local soil, red worms (*Eisenia foetida*) and a proper ratio mix of rice husk, cow dung and biosolid were used. In addition sprinkling water can and thermometer was used.

3.2 Experimental Set up and Data Collection

The study was performed in worm bins of 10-liter capacity. The bins were arranged in completely randomized design with five treatment of C/N ratios namely 15:1, 25:1, 35:1, 45:1, and 55:1 with and without earthworm; replicated three times and 30 sample sizes 15 of them inoculated with earthworm and the remaining were without earthworm (The control). The kind of earthworms used was *Eisenia foetida.* The bins were initially filled to a 2 cm height with 12 mm nominal size chips of stone (aggregates), which was then covered with 2 cm thick layer of 1 to 4 mm size gravel to ensure proper circulation of air and water and bedding material such as compost and local soil is used. A 25 cm layer of mixture of biosolid from (Gonder Beer Factory), cow dung and rice husk in different C/N ratio specifically 15:1, 25:1, 35:1, 45:1 and 55:1 were used above the gravel bed to provide natural habitat to the earthworms. The experimental bins were kept in the shade.

The analysis used for predetermining the mass of the substrates mix used during the experimentation is attached in Appendix 2. The 15 sample bins were incubated with 60 adult *Eisenia foetida* earthworms per each bin for the purpose of vermicomposting and a total of 1800 worms were used. The earthworms were brought from GTZ SUN Amhara. The experimental bins were maintained at moisture content of 70% to ensure the optimum functioning of earthworms. On the other hand the daily evaporated water from the bin was determined using the average mass lost every day for 10 days. The measurement was done at 5:00 pm every day and the lost water was determined by subtracting the finial mass from the initial. Measurement (in gram) shows that 1.94g per day approximately 2g per day was lost. Therefore application of 14g of water or 14ml per week was done throughout the experiment. The experiment was carried out for 70 days since the average days for making vermicompost ranges from 56 to 70 (Ndegwa and Thompson, 2000). Substrates samples were drawn after 70 days from all the experimental bin to analysis same of the chemical properties of vermicompost and compost. About 0.5kg of sample was drawn from each bin. The samples were ground into paste to ensure the homogeneity of the substrate. pH, Organic Matter (%), Available Phosphorus (ppm), Total Nitrogen (%), CEC (cmol+/kg), Exchangeable Calcium (cmol+/kg), Magnesium (cmol+/kg), Potassium (cmol+/kg) and Exchangeable acidity (cmol+/kg) of substrate pastes including the controls (i.e. without earthworm) were measured.

The pH of the samples was measured by pH meter in the supernatant suspension of 1:2.5 ratios of samples to water mixture. Organic carbon was determined by following Walkely, (1947) and Black, (1965) wet oxidation method as described by Jackson, (1968). Available phosphorus was extracted with a sodium bicarbonate solution at pH 8.5 following the procedure described by Oleson, *et al.,* (1954). Total nitrogen was determined by using Kjedahl method as described by Jackson, (1968). Cation exchangeable capacity using ammonium acetate methods as it was described by Jackson, (1968). Exchangeable K, Ca, Mg was determined by Jackson, (1968). Exchangeable Acidity (cmol+/kg) by $BaCl_2$–Triethanolamine reagent by Peech *et al.,* (1962).

Moisture analyses of the ingredients rice husk, cow dung and biosolid were carried out by drying in a hot air oven at 70°C and 75°C for 24 hours and determined using Gravimetric Method. The mean of measured chemical properties of substrates pastes including biomass of earthworm which was measured by exposing the sample to the sun and counting using hand picking were used for analysis.

Data was collected in two stages:-

1) Solving the Moisture and Carbon to Nitrogen Equations Simultaneously

For any number of independent equations we can usually solve for that same number of unknowns. In this case we have two equations (one for moisture and one for the carbon-nitrogen ratio), and we can solve them for any two unknowns. Normally we use this approach to develop a mix ratio of several different ingredients, knowing the moisture, carbon, and nitrogen contents of each. If we specify the quantities of all but two ingredients, and the C/N and moisture content we would like to achieve in the mixture, we can solve for those two remaining quantities to get the mix we want.

In selecting which material quantities to specify and which to solve for as unknowns, it is important to use a little common sense. If our moisture goal is 70%, and we are trying to compost wet cow dung, biosolid, and rice husk, it would be smart to make rice husk one of the unknown quantities, since all the other materials have moisture contents greater than 70%. There is no way to bring the moisture content of a mix down by adding more of a wet ingredient, and, similarly, there is no way to bring the C/N ratio up by adding high nitrogen materials.

Another useful tip, particularly for dry ingredients, is to include water as one of the unknowns. Water will bring up the moisture content without altering the C/N ratio. And since water is cheap and usually readily available, it can be an easy way to develop an appropriate mix.

The solution can be obtained in a number of ways using linear algebra or matrices. With patience, one can use simple algebraic methods to solve the moisture equation for one of the unknown quantities, and then substitute that value in the C/N equation and solve the C/N equation for the other unknown. At that point, back-substitution into the solution of the moisture equation gives both unknowns in terms of known values.

The algebraic manipulations required for a mixture of three materials are straightforward but do take a little time, as is evident from the solution below (Richard, 2002).

The three-ingredient equation for moisture is:

$$G = \frac{M_1 \times Q_1 + M_2 \times Q_2 + M_3 \times Q_3}{Q_1 + Q_2 + Q_3} \qquad \textbf{(Eq. 1)}$$

in which:

Qn = mass of material n ("as is", or "wet weight")

G = moisture goal (%)

Mn = moisture content (%) of material n

And the three ingredient equation for C/N ratio is:

$$R = \frac{Q_1(C_1 \times (100 - M_1) + Q_2(C_2 \times (100 - M_2) + Q_3(C_3 \times (100 - M_3)}{Q_1(N_1 \times (100 - M_1) + Q_2(N_2 \times (100 - M_2) + Q_3(N_3 \times (100 - M_3)} \qquad \textbf{(Eq. 2)}$$

in which:

R = goal (C/N ratio)

Cn = carbon (%)

Nn = nitrogen (%)

and Mn and Qn are as previously defined

The resulting solutions are:

(Eq. 3)

$$Q_2 = \frac{A}{B} \quad and \quad Q_3 = \frac{C}{B}$$

Where:

A = Q1 (M1 C3 (100 - M3) - M1 R N3 (100 - M3) - M3 C1 (100 - M1) + R N3 (100 - M3)G - R N1 (100 - M1)G +C1 (100 - M1)G - C3 (100 - M3)G +M3 R N1 (100 - M1))

B = R N2 (100 - M2)G - R N2 (100 - M2) M3 - R N3 (100 - M3)G + R N3 (100 - M3)M2 - C2 (100 - M2)G + C2 (100 - M2)M3 + C3 (100 - M3)G - C3 (100 - M3)M2

C = Q1 (R N1 (100 - M1) G - R N1 (100 - M1) M2 -R N2 (100 - M2) G + R N2 (100 - M2) M1 - C1 (100 -M1) G + C1 (100 - M1) M2 + C2 (100 - M2)G - C2 (100 - M2) M1)

To see how this equation works, plug in the material characteristics from our previous example with cow dung and rice husk, and the biosolid characteristics given below. Then solve for the quantity of rice husk and/or biosolid needed to optimize C/N and moisture for 10 kg of cow dung.

Ingredient Characteristics:		Moisture	Carbon	Nitrogen
Cow dung:	Q1 = 10	M1 = 80.5% H_2O	C1 = 7.9% carbon	N1 = 0.3% nitrogen
Biosolid:	Q2 =?	M2 = 79.8% H_2O	C2 = 4.4% carbon	N3 = 1.3% nitrogen
Rice husk:	Q3 =?	M3 = 8.3% H_2O	C3 = 23.4% carbon	N3 = 0.2% nitrogen
Mixture Goals:				
Moisture:	G = 70%			
C/N ratio:	R = 55			

We will find:

Q2 = 0.22 kg and Q3 = 1.74 kg

Thus if we mix 0.22kg of biosolid and 1.74kg of rice husk with the initial 10 kg cow dung, the mixture will achieve our goals of 70% moisture and a 55:1 C/N ratio.

Note that this simultaneous solution for three ingredients depends entirely on having the right three ingredients to combine. With many combinations the resulting Q2 and/or Q3 will be negative, indicating that no solution is possible. In that case you can add an additional material to add to the mix, such as sawdust or wood chips if the moisture or nitrogen levels are too high. Of course, if we add more ingredients, we also need a different formula to determine the solution.

For increasing numbers of materials, this formula becomes even more complicated. The solution for a mixture of four ingredients follows.

The four-ingredient equation for moisture is:

$$G = \frac{M_1 \times Q_1 + M_2 \times Q_2 + M_3 \times Q_3 + M_4 \times Q_4}{Q_1 + Q_2 + Q_3 + Q_4} \qquad \textbf{(Eq. 4)}$$

and the four ingredient equation for C/N ratio is:

$$R = \frac{Q_1(C_1 \times (100 - M_1)) + Q_2(C_2 \times (100 - M_2)) + Q_3(C_3 \times (100 - M_3)) + Q_4(C_4 \times (100 - M_4))}{Q_1(N_1 \times (100 - M_1)) + Q_2(N_2 \times (100 - M_2)) + Q_3(N_3 \times (100 - M_3)) + Q_4(N_4 \times (100 - M_4))} \qquad \textbf{(Eq. 5)}$$

Where all terms are as previously defined

If we know the carbon, nitrogen, and moisture contents of each of these materials, specifies goals for moisture and C/N ratio of the mixture, and quantities of Q1 and Q2, then we can solve for Q3 and Q4. The solution is:

$$Q_3 = \frac{D}{E} \quad \text{and} \quad Q_4 = \frac{F}{E} \qquad \textbf{(Eq. 6)}$$

Where

D=-(Q1C4(100-M4)G+Q2C4(100-M4)G-Q2C2(100-M2)G-Q1C1(100-M1)G
-Q1RN4(100-M4)G-Q2RN4(100-M4)G+RQ1N1(100-M1)G+RQ2N2(100-M2)G
-M4RQ1N1(100-M1)-M1Q1C4(100-M4)+M4Q1C1(100-M1)-M2Q2C4(100-M4)
-M4RQ2N2(100-M2)+M1Q1RN4(100-M4)+M4Q2C2(100-M2)+M2Q2RN4(100-M4))

E= RN3(100-M3)G-RN3(100-M3)M4-C3(100-M3)G+C3(100-M3)M4-RN4(100-M4)G
+RN4(100-M4)M3+C4(100-M4)G-C4(100-M4)M3

and

F=-RN3(100-M3)GQ1-RN3(100-M3)GQ2+RN3(100-M3)M1Q1
+RN3(100-M3)M2Q2+C3(100-M3)GQ1+C3(100-M3)GQ2
-C3(100-M3)M1Q1-C3(100-M3)M2Q2+RQ1N1(100-M1)G
-RQ1N1(100-M1)M3+RQ2N2(100-M2)G-RQ2N2(100-M2)M3
-Q1C1(100-M1)G+Q1C1(100-M1)M3-Q2C2(100-M2)G+Q2C2(100-M2)M3

There is also a model for calculation of moisture and carbon/nitrogen ratio using spreadsheet developed by Richard, (2002). The experiment was done using this spreadsheet and the results are shown in the Appendix 2.

2) Distribution of the determined substrates mix

Completely Randomize Design (CRD) technique was used for distribution of the substrates mix that was specified during the first stage. Diagrammatical representation of the randomization process is shown below.

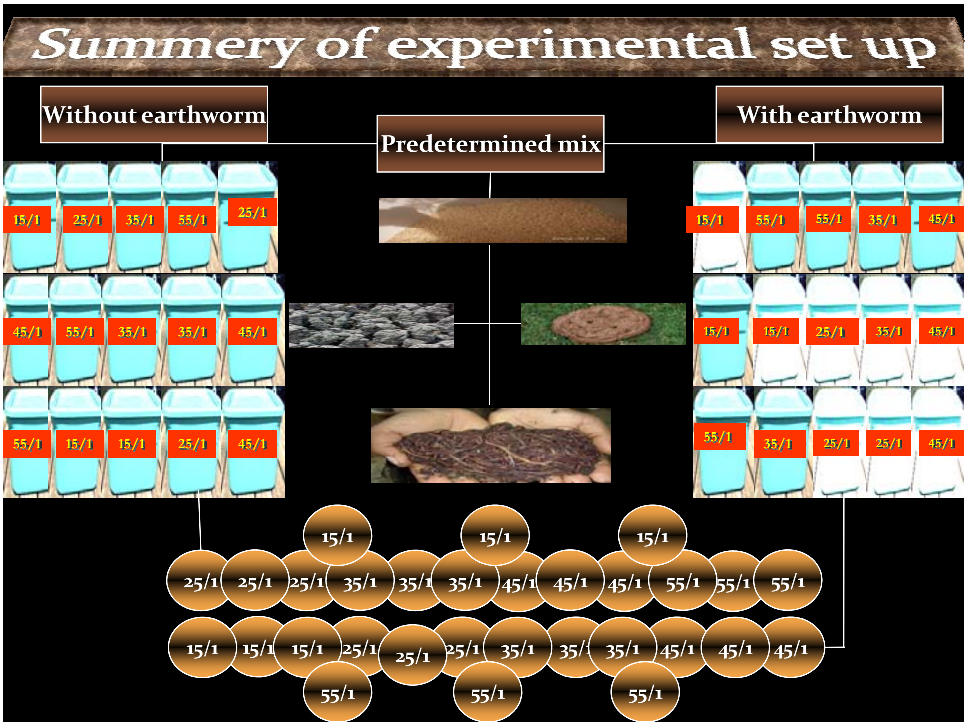


Figure 1: Distribution of the Determined Substrates Mix

3.3 Analyses of the Experiment

Some of the chemical properties of the samples from which the soil laboratory analysis was conducted during the period of experimentation were subjected to oneway analysis of variance (ANOVA) Tukey-Kramer HSD with carbon to nitrogen ratio as the main factor will be used to test significance of mean differences in chemical properties of the samples ($\alpha = 0.05$) using JMP-5 procedures of the statistical analysis system (SAS institute, 2002). ANRS Bureau of Agriculture and Rural Development Gondar soil testing laboratory analysis result sheet is attached in Appendix 3.

3.4 Limitations of the Study

This study focused only on the effects of carbon to nitrogen ratio of the substrates. It did not indicate the upshot of the other chemical properties of the substrates on vermicomposting. The statistical analysis based only on limited number of chemical properties of vermicompost therefore, additional nutrients and same physical properties should be analyzed. Other limitations of the study were the natural aversion of the people to worms but this was overcome through education and awareness on the good aspects of earthworms. Furthermore it is a little bit difficult to control the moisture content of the substrates mix at 70% throughout the experiment because of the external weather factors. Finally, due to large range between the treatments of C/N ratio and the above mentioned factors it required additional research.

Chapter 4: Results and Discussions

4.1 Results

4.1.1 Variation of Same of the Chemical Properties of the Samples as a Result of C/N ratio of the Substrata

Data of measured variables (chemical properties) of the samples namely pH, Organic Carbon, Available P, Total N, CEC, Exchangeable Ca, Exchangeable K, Exchangeable Mg, and Exchangeable Acidity at different C/N ratio of vermicomposting and composting materials are given in Tables (1 - 9) of Appendix 4. Analysis of variance was carried out to see the significance of variability of chemical properties at ($\alpha = 0.05$) for the different C/N ratios of the samples materials with and without earthworm. The analyses output for these data are shown in Table 1 and 2, and in Figures 2 – 4.

Table1. Effects of C/N ratio on Chemical Properties of the Samples

C/N ratio	pH	Organic carbon (%)	Available P(ppm)	Total N (%)	CEC (cmol+/kg) Amm.acet.)	Ex. Ca (cmol+/kg)	Ex. K (cmol+/kg)	Ex. Mg (cmol+/kg)	Ex. Acidity (cmol+/kg)
15/1wo**	6.45 ^{bc}	21.29 ^{b}	4.70 ^{b}	1.25 ^{a}	55.35 ^{a}	32.18 ^{ab}	4.38 ^{ab}	10.73 ^{a}	2.57 ^{a}
25/1wo**	7.03 ^{ab}	22.07 ^{b}	5.47 ^{ab}	1.86 ^{a}	44.77 ^{b}	26.64 ^{abc}	6.49 ^{ab}	7.77 ^{a}	1.56 ^{a}
35/1wo**	7.32 ^{ab}	22.63 ^{b}	5.30 ^{ab}	1.61 ^{a}	41.66 ^{b}	19.98 ^{c}	5.90 ^{ab}	9.99 ^{a}	2.14 ^{a}
45/1wo**	7.80 ^{ab}	25.13 ^{b}	5.63 ^{ab}	1.45 ^{a}	40.32 ^{b}	32.19 ^{ab}	3.06 ^{b}	9.62 ^{a}	0.49 ^{a}
55/1wo**	6.63 ^{abc}	19.23 ^{b}	6.51 ^{ab}	1.60 ^{a}	41.41 ^{b}	25.52 ^{bc}	4.54 ^{ab}	11.84 ^{a}	1.87 ^{a}
15/1w*	5.64 ^{c}	26.27 ^{ab}	6.48 ^{ab}	1.30 ^{a}	48.84 ^{ab}	36.26 ^{a}	7.24 ^{a}	17.41 ^{a}	1.47 ^{a}
25/1w*	6.97 ^{abc}	34.22 ^{a}	7.28 ^{a}	1.14 ^{a}	48.69 ^{ab}	32.18 ^{ab}	7.06 ^{a}	10.73 ^{a}	1.21 ^{a}
35/1w*	7.57 ^{ab}	19.67 ^{b}	6.42 ^{ab}	1.22 ^{a}	45.43 ^{ab}	25.90 ^{abc}	6.53 ^{ab}	10.73 ^{a}	0.87 ^{a}
45/1w*	7.34 ^{ab}	20.83 ^{b}	6.85 ^{ab}	1.14 ^{a}	49.36 ^{ab}	30.71 ^{ab}	2.99 ^{b}	12.95 ^{a}	0.91 ^{a}
55/1w*	7.82 ^{a}	22.49 ^{b}	6.53 ^{ab}	0.99 ^{a}	50.02 ^{ab}	25.53 ^{bc}	7.49 ^{a}	22.20 ^{a}	0.71 ^{a}
Rsquire	0.74	0.75	0.60	0.33	0.70	0.69	0.71	0.37	0.35
Prob > F	0.0003	0.0002	0.0127	0.3995	0.0012	0.0013	0.0009	0.2938	0.3482

w* = with earthworm

wo** = without earthworm

In each column means with similar letters do not significantly differ ($P \geq 0.05$)

Figure 2: Effects of C/N ratio on Chemical Properties of Vermicompost

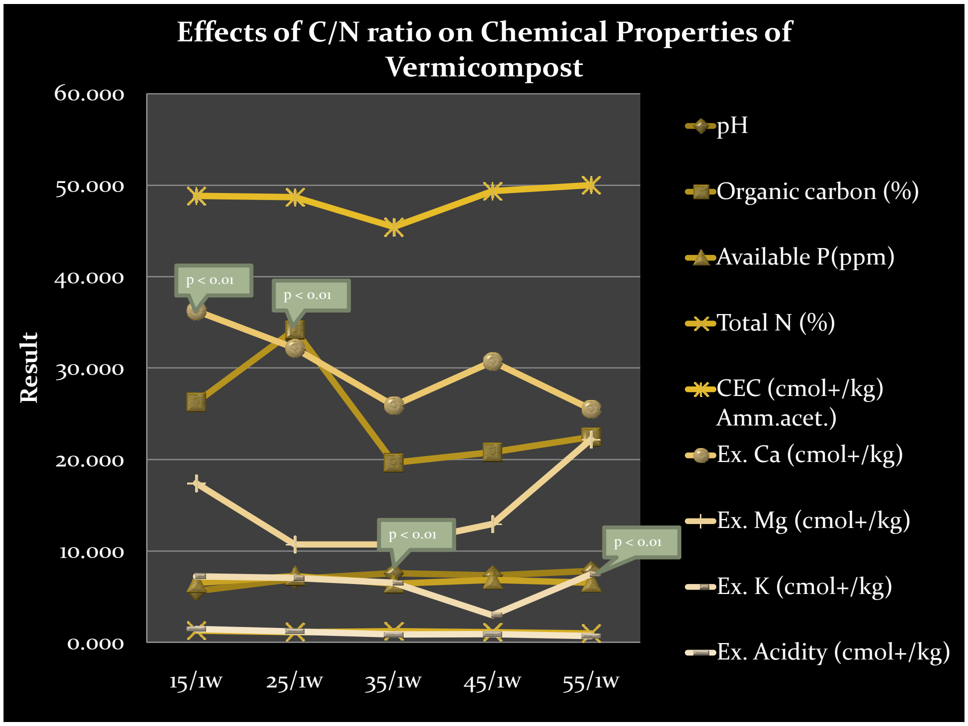


Figure 3: Effects of C/N ratio on Chemical Properties of Compost

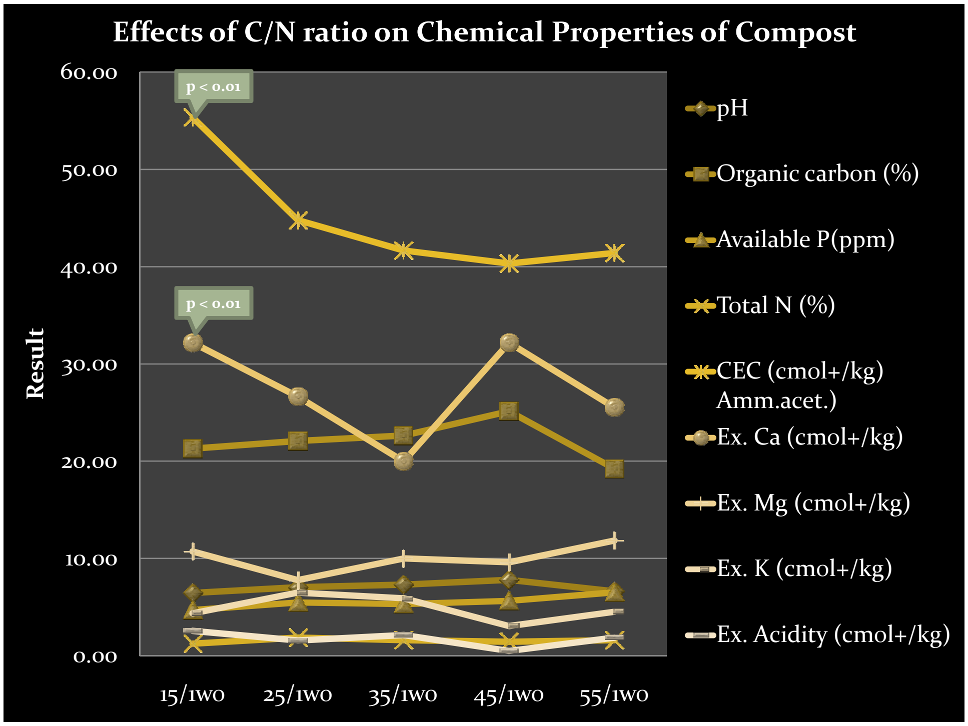
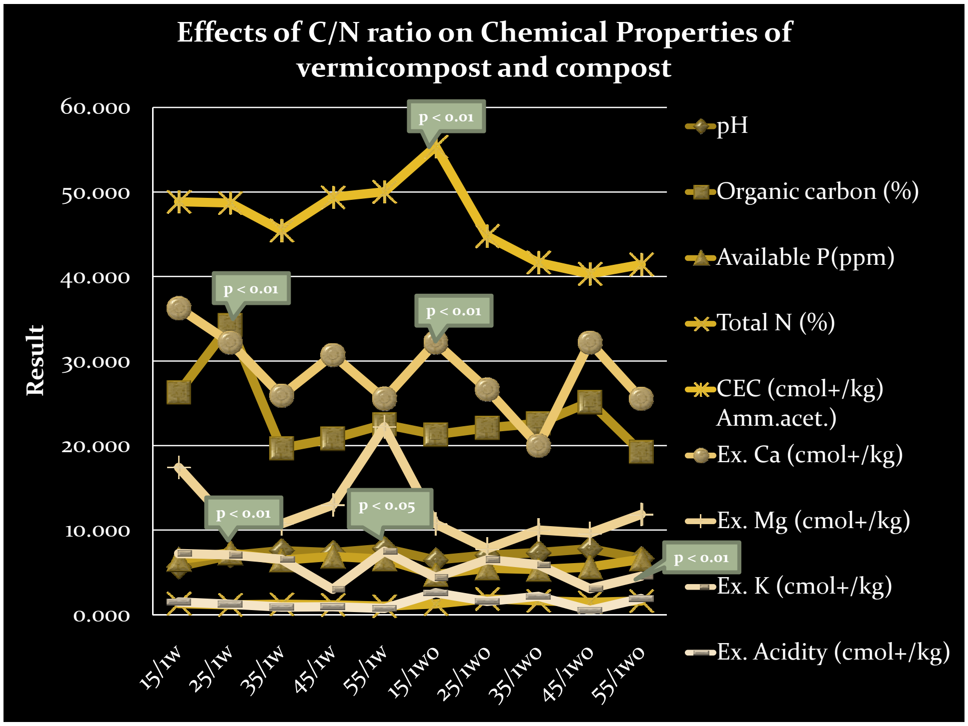


Figure 4: Effects of C/N ratio on Chemical Properties of Vermicompost and Compost



The results showed that pH, Organic Carbon, Available P concentrations were significantly ($P < 0.01$) affected by C/N ratios and earthworm treatments .The highest and lowest pH values were observed at C/N ratios of 55:1 with earthworm, and 15:1 with and without earthworm respectively, the treatment 25:1 C/N ratio with earthworm has relatively neutral of pH. On the other hand, the treatment 25:1 C/N ratio with earthworm had significantly ($P < 0.01$) increased organic carbon as compared to the control and the other treatments except 15/1 C/N ratio with earthworm. In addition, the mixture treated with earthworm at 25:1 C/N ratio had significantly ($P < 0.05$) the highest available P as compared to 15/1 C/N ratio without earthworm. The analysis farther revealed that the contents of variables Total N, Exchangeable Mg and Exchangeable Acidity (Al^{+3} and H^{+}) not significantly different ($P \geq 0.05$).

The substrata mix without earthworm at C/N ratio 15:1 had significantly ($P < 0.01$) higher CEC than those mixtures without earthworm at C/N ratios 25:1, 35:1, 45:1 and 55:1. On the other hand, the earthworm at 15/1 C/N ratio increased exchangeable Ca content of the mixture significantly ($P < 0.01$) as compared to 35/1 C/N ratio without earthworm, 55/1 with and without earthworm. The highest increase of exchangeable Ca was found at 15:1 C/N ratios with earthworm, 45:1 and 15:1 without earthworm, and 25:1 and 45:1 with earthworm respectively. Besides, inoculation of earthworm at rate of 55:1, 15:1 and 25:1 C/N ratios significantly ($P < 0.01$) increased exchangeable K in comparison to 45/1 C/N ratio with and without the earthworm.

4.2 Discussions

Addition of earthworm in mixture of the ingredients rice husk, cow dung and biosolid at different C/N ratio vary in pH. The pH concentrations were significantly ($P < 0.01$) affected by C/N ratio and earthworm treatments (Table 1). The highest and lowest pH values were observed at the rate of C/N ratio of 55:1 with earthworm and 15:1 with and without earthworm respectively. This could be due to the materials used for vermicomposting especially the biosolid rich in active fraction of organic matter and NH_4^+, CO_2 and organic acids product of respiration and different microbial metabolism during vermicomposting and composting may contributed to the decrease in pH as it was described by Albanell *et al*., (1988).

On the other hand, from the result it is clearly shown that the mixture of rice husk, cow dung and biosolid treated with earthworm at the rate of 25:1 C/N ratio had significantly increased organic carbon ($P < 0.01$) as compared to control and the other treatments except 15/1 C/N ratio with earthworm (Table 1). This indicates that the continuous inputs of organic carbon to the 25:1 C/N ratio were probably from slowly miniralization of the material used especially rice husk and neutral of pH which favored the activity of the earthworm to release organic carbon effectively. The excrated polysaccharides in the earthworm gut could also be responsible for this increase as it was described by Lui *et al*., (1991).

Phosphorus is essential for plant growth. In this trial the mixture treated with earthworm at the rate of 25:1 C/N ratio had significantly ($P < 0.05$) increased available phosphorous as compared to 15/1 C/N ratio without earthworm (Table 1). The enhancement of phosphates activity and physical breakdown of material resulted in greater mineralization studies by Sharpley and Syres, (1977) have also show similar result. The increased available phosphorous probably due to the contribution of relatively neutral of pH that the 25:1 carbon to nitrogen ratio had; and may be because of inoculation of earthworm which facilitate phosphorous miniralization. Or else it could be conclude that the continuous inputs of P were probably from slow release from vermicompost and release of P was due largely to the activity of microorganisms as it was shown by Arancon *et al*., (2006). In addition, most probably available p levels increase due to mineralaization after egestion as it was shown by Hynes *et al*., (1999).

Conversely, the above results indicate that the total N concentration not significantly different between treatments ($P \geq 0.05$) (Table 1). This could be probably due to the biosolid and cow dung that contain readily mineralizable substrates that stimulate earthworm and microbial growth. This effect was most pronounced two months after adding the earthworm, when both the total amount of earthworm biomass and number were greater due to N immobilization. Earthworms were more than doubled in size and number during the course of the experiment that was from 3g to 6g and from 60 per each of the 15 bin to 350 adults and 600 newly hatched on average and many eggs at the end of the experiment Appendix 5. Though, the earthworms in 15:1 C/N ratio did not produce eggs instead number was reduced from 60 initial to 30 latter and after 60 days they all died. This may be due to the increased acidity in the treatment 15/1 C/N ratio as compared to the others. In general, irrespective of vermiculture media, the N content in vermicompost was higher than in the vermicomposting (input) materials Appendix 1. On the other hand, (Daniel and Anderson, 1992) describes that production of castings, earthworm dead tissue, nitrogen excretion and stimulated activity of N-fixing bacteria during the vermicomposting process would have been responsible for higher N content in vermicompost. Others also found available N increased irrespective of the residues the earthworms feed on or the growth temperature, that was attributed to the increase in oxidized C due to soil ingestion, and not due to change in soil texture as the soil was not mixed (Ruz-Jerez, 1992). According to (Lavelle, 1992), high levels of ammonium are found in fresh casts due to the excretion of NH_4^+ through the endonephridia gland into the gut, and the mineralization of soil organic matter by the ingested soil microflora in the middle and posterior part of the gut.

The cation exchange capacity (CEC) is a value given on a soil analysis report to indicate its capacity to hold cation. The CEC, however, is not something that is easily adjusted. It is a value that indicates a condition or possibly a restriction that must be considered when working with this particular mixture of vermicomposting materials. What is more, the substrates rice husk, cow dung and biosolid mixture without earthworm at carbon to nitrogen ratio 15/1 had significantly ($P < 0.01$) higher CEC than those mixture without earthworm at carbon to nitrogen ratio 25:1, 35:1, 45:1 and 55:1 respectively this is because C/N ratio 15/1 without earthworm has got relatively higher Ca, K, Mg (Table 1). However, the CEC of the mixture might depend on the raw materials used for vermicomposting and their ion concentration as it was described by Atiyeh *et al*., (2002b).

In addition to the above, the testing indicated that earthworm at 15/1 C/N ratio increased Ca content significantly ($P < 0.05$) as compared to 35/1 C/N ratio without earthworm, 55/1 C/N ratio with and without earthworm. The highest increase of Ca was at 15:1 C/N ratio with earthworm, 45:1 and 15:1 C/N ratio without earthworm, and 25:1 and 45:1 C/N ratio with earthworm respectively (Table 2). Vermicompost contains most nutrients in plant available forms such as phosphates, exchangeable calcium. Similar result was found by Orozeo *et al*., (1996).

Furthermore, the above results revealed that the exchangeable Mg and exchangeable acidity (Al^{+3} and H^{+}) concentration not significantly ($P \geq 0.05$) different between treatments (Table 2). On the contrary other studies found that vermicompost significantly contains nutrients such as nitrates and magnesium (Edwards & Burrows 1988; Orozco *et al.* 1996).

Inoculation of earthworm at rate of 55:1, 15:1 and 25:1 C/N ratio significantly ($P < 0.01$) increased exchangeable K respectively in comparison to 45/1 C/N ratio with and without earthworm. The selective feeding of earthworm on organically rich substances which breakdown during passage through the gut, biological grinding, together with enzymatic influence on finer soil particles, were likely responsible for increasing the different forms of K as it was described by Rao *et al.,* (1996). Others also found that the increase of soil organic matter resulted in decrease K fixation and subsequent increase K availability (Olk and Cassman, 1993).

Above all from the result it can be deduce that those treatments with earthworm at 25/1 C/N ratio have numerically has got more organic carbon, available phosphorus, exchangeable potassium, exchangeable calcium and relatively neutral of pH. Similar results were found by Ndegwa and Thompson, (2000) that was illustrated as the C/N ratio which results in the most stable earthworm casts is 25/1.

Chapter 5: Conclusion and Recommendation

5.1 Conclusion

The objective of this study was to use biosolids in a vermicomposting process with *Eisenia foetida* specifically, to investigate and establish a suitable C/N ratio for vermicomposting of fresh biosolids amended with rice husk and cow dung. The nutrient analysis shows that possibility of biosolid to be used as vermicomposting material and available phosphorous, organic carbon; calcium and potassium have relatively increased with the presence of earthworm as compared to the controls.

To be specific in this experiment the mixture treated with earthworm on carbon to nitrogen ratio of 25:1 had considerably increased phosphorus, potassium, organic carbon levels and created favorable condition for earthworm to survive and reproduce. However, the exchangeable acidity and Mg concentration did not differ significantly between treatments. Also the total N concentration did not differ significantly between treatments but there was variation of earthworm growth and reproduction among the treatments.

Earthworms are useful in organic waste recycling. If a large number of adult worms (60 to 70) are introduced into 18 Kg of a 25 cm-deep compost substrates, covered with fine material and optimum conditions provided, mature vermicompost can be produced within as little as 60 days. Vermicomposts have excellent chemical and physical properties that compare favorably to traditional composts. Earthworms eat and mix a large amount of soil and organic matter, then deposit their castings (vermicompost). The vermicompost contains high concentration of organic material and is rich in many soil nutrients such as nitrogen, potash, phosphorus, calcium, magnesium, etc. In soil, much of the phosphorus is bound in organic matter in a form that is not available to plants. Earthworms change the phosphorus into a form that the plant roots can easily absorb. The mixing action of the earthworms can also make slow-release forms of phosphorus fertilizers more readily available.

Earthworms also produce enzymes which break complex biomolecules present in the garbage into simple compounds which are utilized by the micro-organisms. The micro-organisms in the worms gut also produce useful compounds all of which are present in its castings. The earthworms provide ideal temperature, pH and oxygen concentration for the speedy growth of useful microorganisms and plants.

Overall *Eisenia foetida* make composting indoors feasible because they are very efficient processors of organic waste; they eat and expel their own weight every day. Even a small bin of *Eisenia foetida* will yield pounds of rich compost, also known as worm castings. *Eisenia foetida* is extremely prolific. It takes about three weeks for fertilized eggs to develop in a cocoon from which three or more young worms can hatch. In two months the worms become sexually mature and will start breeding.

5.2 <u>Recommendation</u>

One of the major environmental concerns is land degradation, since there is an increasing awareness that soil is a critical component of the biosphere, not only by the production of food but also by the maintenance of environmental quality. Inappropriate production technologies have resulted in soil quality deterioration, leading to soil organic matter losses and structure degradation, affecting water, air and nutrient flows, and consequently plant growth. Soil organic matter decline in many agro-ecosystems occurs because losses of carbon through oxidation and erosion by intensive cropping are not compensated by carbon inputs through the return of plant biomass. Organic matter reduction is, in turn, associated with the soil structure degradation. These and other facts have breathed life into global interest in organic recycling practices such as vermicomposting. Vermicomposting, a novel technique of converting decomposable organic wastes into valuable vermicompost through earthworm activity, especially at C/N ratio 25/1, which is a faster and good process than the conventional methods of compost preparation. Within a very short period of time nutrient rich good quality compost is prepared which is highly efficient, cost effective and ecologically sound input for agriculture.

Earthworms grind the organic waste materials in the gizzard and the actions of bacteria therein hasten the decomposition process. Species to be used for vermicomposting should have good survival in dense organic matter bed, high carbon consumption, and digestion and assimilation rate. The red earthworm *(Eisenia foetida*) is the world's most widely used species for the process of vermicomposting.

Therefore, developing countries like Ethiopia which has more of organic wastes can efficiently utilize this cost effective, environmentally sound technology and together we can make it socially acceptable. Finally additional research on the physical and chemical properties of vermicomposting should be done besides field experiment on the respond of different crops to vermicompost should be evaluated.

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Appendix

1: ANRS, Rural Road Authority, Bahir Dar, Ethiopia Nutrient and Moisture Contents Analysis of Different Materials Results

S. No.	Ingredients	Moisture (%)	Carbon (%)	Nitrogen (%)
1	Cow dung	80.50	7.9	0.3
2	Biosolid	79.80	4.4	1.3
3	Rice husk	8.30	23.4	0.2

2: Calculated Mass of Ingredients using the Moisture and Carbon to Nitrogen Equation Model

Ingredient	% Moisture	% Carbon	% Nitrogen	Mass (kg or lbs.)	
Cow dung	80.5	7.9	0.3	10.00	
Biosolid	79.8	4.4	1.3	0.22	} Note:
Rice husk	8.3	23.4	0.2	1.74	} these masses are solved for in
Water	100.0	0.0	0.0	0.00	} some of the equations below.
			Calculated mixture moisture content:	**70.0**	(masses as specified)
			Calculated mixture C/N ratio:	**55.0**	(masses as specified)
The required mass of the third material can be determined given characteristics, the masses of the first two, and goals:					
	moisture goal:	70.0	(set these goals to match your requirements)		
	C/N ratio goal:	55.0			
				Calculated mass of second ingredient:	Biosolid
					0.22
				Calculated mass of third ingredient:	Rice husk
					1.74
				Calculated mass of third ingredient:	Rice husk
					1.74
				Calculated mass of fourth ingredient:	water
					0.00

Ingredient	% Moisture	% Carbon	% Nitrogen	Mass (kg or lbs.)	
Cow dung	80.5	7.9	0.3	10.00	
Biosolid	79.8	4.4	1.3	1.31	} Note:
Rice husk	8.3	23.4	0.2	1.91	} these masses are solved for in
Water	100.0	0.0	0.0	0.00	} some of the equations below.
			Calculated mixture moisture content:	**70.0**	(masses as specified)
			Calculated mixture C/N ratio:	**45.0**	(masses as specified)
The required mass of the third material can be determined given characteristics, the masses of the first two, and goals:					
	moisture goal:	70.0	(set these goals to match your requirements)		
	C/N ratio goal:	45.0			
				Calculated mass of second ingredient:	Biosolid
					1.31
				Calculated mass of third ingredient:	Rice husk
					1.91
				Calculated mass of third ingredient:	Rice husk
					1.91
				Calculated mass of fourth ingredient:	water
					0.00

Ingredient	% Moisture	% Carbon	% Nitrogen	Mass (kg or lbs.)	
Cow dung	80.5	7.9	0.3	10.00	
Biosolid	79.8	4.4	1.3	3.47	} Note:
Rice husk	8.3	23.4	0.2	2.25	} these masses are solved for in
Water	100.0	0.0	0.0	0.00	} some of the equations below.
			Calculated mixture moisture content:	**70.0**	(masses as specified)
			Calculated mixture C/N ratio:	**35.0**	(masses as specified)
The required mass of the third material can be determined given characteristics, the masses of the first two, and goals:					
	moisture goal:	70.0	(set these goals to match your requirements)		
	C/N ratio goal:	35.0			
				Calculated mass of second ingredient:	Biosolid
					3.47
				Calculated mass of third ingredient:	Rice husk
					2.25
				Calculated mass of third ingredient:	Rice husk
					2.25
				Calculated mass of fourth ingredient:	water
					0.00

Ingredient	**% Moisture**	**% Carbon**	**% Nitrogen**	**Mass (kg or lbs.)**	
Cow dung	80.5	7.9	0.3	5.00	
Biosolid	79.8	4.4	1.3	4.92	} Note:
Rice husk	8.3	23.4	0.2	1.63	} these masses are solved for in
Water	100.0	0.0	0.0	0.00	} some of the equations below.
			Calculated mixture moisture content:	**70.0**	(masses as specified)
			Calculated mixture C/N ratio:	**25.0**	(masses as specified)
The required mass of the third material can be determined given characteristics, the masses of the first two, and goals:					
	moisture goal:	70.0	(set these goals to match your requirements)		
	C/N ratio goal:	25.0			
				Calculated mass of second ingredient:	Biosolid
					4.92
				Calculated mass of third ingredient:	Rice husk
					1.63
				Calculated mass of third ingredient:	Rice husk
					1.63
				Calculated mass of fourth ingredient:	water
					0.00

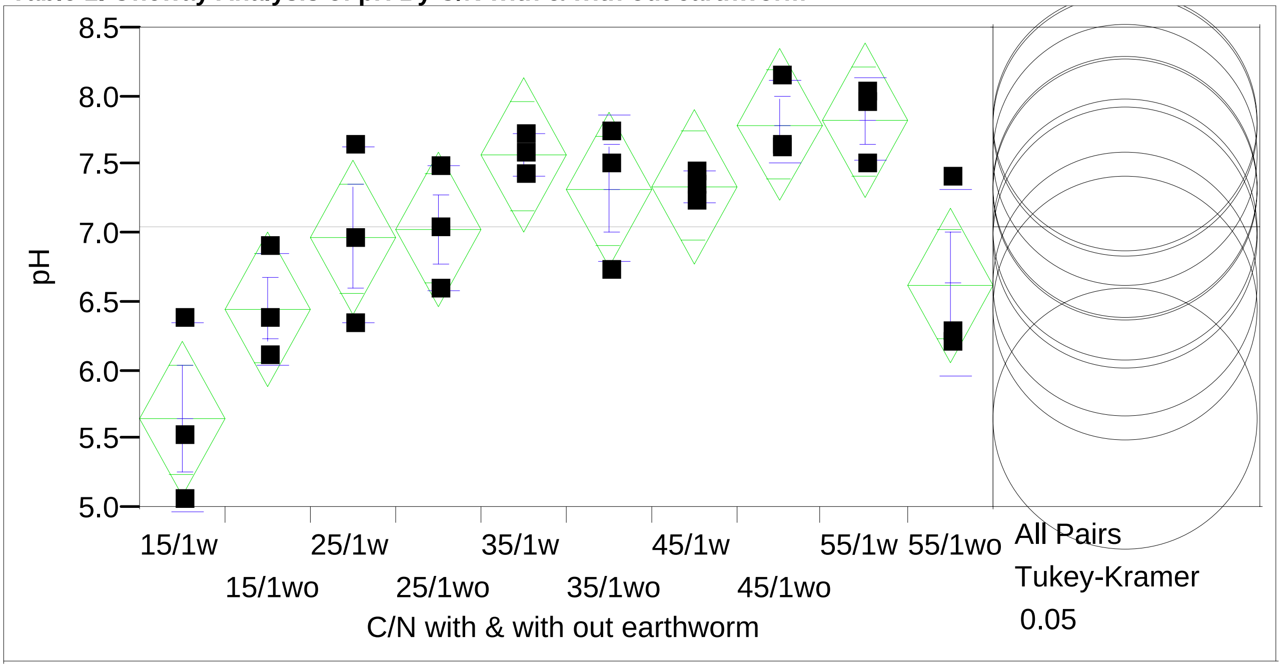
Ingredient	**% Moisture**	**% Carbon**	**% Nitrogen**	**Mass (kg or lbs.)**	
Cow dung	80.5	7.9	0.3	0.50	
Biosolid	79.8	4.4	1.3	12.18	} Note:
Rice husk	8.3	23.4	0.2	1.98	} these masses are solved for in
Water	100.0	0.0	0.0	0.00	} some of the equations below.
			Calculated mixture moisture content:	**70.0**	(masses as specified)
			Calculated mixture C/N ratio:	**15.0**	(masses as specified)
The required mass of the third material can be determined given characteristics, the masses of the first two, and goals:					
	moisture goal:	70.0	(set these goals to match your requirements)		
	C/N ratio goal:	15.0			
				Calculated mass of second ingredient:	Biosolid
					12.18
				Calculated mass of third ingredient:	Rice husk
					1.98
				Calculated mass of third ingredient:	Rice husk
					2.02
				Calculated mass of fourth ingredient:	water
					0.00

3: ANRS Bureau of Agriculture & Rural Development Gondar soil testing laboratory analysis result sheet

No.	C/N with (w) & without (wo) earthworm	pH	Organic carbon (%)	Available P(ppm)	Total N (%)	CEC (cmol+/kg) Amm.acet.)	Ex. Ca (cmol+/kg)	Ex. Mg (cmol+/kg)	Ex. K (cmol+/kg)	Ex. Acidity (cmol+/kg)
1.	15/1w	5.04	29.64	6.92	1.32	52.17	39.96	26.7	7.03	2.66
2.	15/1w	6.38	26.03	6.27	1.52	43.29	35.52	14.43	8.19	1.51
3.	15/1w	5.52	23.16	6.27	1.06	51.06	33.3	11.1	6.51	0.26
4.	25/1w	6.34	33.43	7.7	1.32	44.19	34.41	8.88	5.68	0.8
5.	25/1w	7.63	37.73	7.6	1.06	48.84	27.75	12.21	8.35	1.64
6.	25/1w	6.95	31.52	6.55	1.06	53.06	34.4	11.11	7.15	1.19
7.	35/1w	7.72	19.44	7.43	1.28	48.84	33.3	5.55	8.25	1.24
8.	35/1w	7.42	18.05	6.11	1.29	46.17	22.2	15.54	4.5	0.89
9.	35/1w	7.58	21.52	5.74	1.09	41.3	22.2	11.1	6.86	0.49
10.	45/1w	7.23	20.83	6.91	1.16	48.62	33.3	8.88	3.04	1.15
11.	45/1w	7.45	21.94	7.3	0.98	52.17	31.08	13.32	2.71	0.71
12.	45/1w	7.35	19.72	6.35	1.28	47.3	27.75	16.65	3.22	0.89
13.	55/1w	7.95	20.83	6.24	1.13	50.17	22.2	18.87	6.68	0.71
14.	55/1w	7.49	20.41	5.7	1.02	52.83	27.75	29.97	7.68	0.8
15.	55/1w	8.03	26.24	7.67	0.83	47.06	26.64	17.76	8.11	0.62
16.	15/1wo	6.90	21.38	4.24	1.52	57.05	32.18	21.09	5.06	1.24
17.	15/1wo	6.10	20.69	5.02	0.16	55.5	31.08	8.88	3.22	4
18.	15/1wo	6.37	21.8	4.86	2.08	53.51	33.3	2.22	4.87	2.48
19.	25/1wo	6.59	21.52	5.23	1.97	42.62	26.64	2.22	5.92	1.68
20.	25/1wo	7.04	20.41	5.2	1.98	48.4	31.08	7.77	6.87	2.35
21.	25/1wo	7.48	24.3	5.98	1.63	43.29	22.2	13.32	6.69	0.67
22.	35/1wo	7.50	23.19	5.52	1.82	39.96	15.54	12.21	8.78	1.24
23.	35/1wo	6.73	17.35	5.15	2.12	43.29	19.98	3.33	4.08	4.62
24.	35/1wo	7.74	27.35	5.25	0.91	41.73	24.42	14.43	4.84	0.58
25.	45/1wo	7.62	23.74	4.76	1.61	39.96	33.3	11.1	3.79	0.58
26.	45/1wo	7.63	25.97	6.55	1.4	39.96	29.97	6.66	3.24	0.53
27.	45/1wo	8.15	25.69	5.59	1.36	41.05	33.3	11.1	2.17	0.36
28.	55/1wo	7.41	24.3	7.9	1.32	41.87	27.75	23.31	3.39	0.44
29.	55/1wo	6.28	16.45	5.05	2.31	34.63	22.2	4.44	4.62	3.33
30.	55/1wo	6.20	16.94	6.6	1.18	47.73	26.62	7.77	5.61	1.86

4: Data analysis using JMP model

Table 1. Oneway Analysis of pH By C/N with & with out earthworm



Oneway Anova
Summary of Fit

Rsquare	0.73741
Adj Rsquare	0.619245
Root Mean Square Error	0.467853
Mean of Response	7.060667
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C/N with & with out earthworm	9	12.293653	1.36596	6.2405	0.0003
Error	20	4.377733	0.21889		
C. Total	29	16.671387			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15/1w	3	5.64667	0.27012	5.0832	6.2101
15/1wo	3	6.45667	0.27012	5.8932	7.0201
25/1w	3	6.97333	0.27012	6.4099	7.5368
25/1wo	3	7.03667	0.27012	6.4732	7.6001
35/1w	3	7.57333	0.27012	7.0099	8.1368
35/1wo	3	7.32333	0.27012	6.7599	7.8868
45/1w	3	7.34333	0.27012	6.7799	7.9068
45/1wo	3	7.80000	0.27012	7.2365	8.3635
55/1w	3	7.82333	0.27012	7.2599	8.3868
55/1wo	3	6.63000	0.27012	6.0665	7.1935

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
15/1w	3	5.64667	0.678921	0.39198	3.9601	7.3332
15/1wo	3	6.45667	0.406981	0.23497	5.4457	7.4677
25/1w	3	6.97333	0.645316	0.37257	5.3703	8.5764
25/1wo	3	7.03667	0.445009	0.25693	5.9312	8.1421
35/1w	3	7.57333	0.150111	0.08667	7.2004	7.9462
35/1wo	3	7.32333	0.527668	0.30465	6.0125	8.6341
45/1w	3	7.34333	0.110151	0.06360	7.0697	7.6170
45/1wo	3	7.80000	0.303150	0.17502	7.0469	8.5531
55/1w	3	7.82333	0.291433	0.16826	7.0994	8.5473
55/1wo	3	6.63000	0.676683	0.39068	4.9490	8.3110

Means Comparisons

Dif=Mean[i]-Mean[j]	55/1w	45/1wo	35/1w	45/1w	35/1wo	25/1wo	25/1w	55/1wo	15/1wo	15/1w
55/1w	0.0000	0.0233	0.2500	0.4800	0.5000	0.7867	0.8500	1.1933	1.3667	2.1767
45/1wo	-0.0233	0.0000	0.2267	0.4567	0.4767	0.7633	0.8267	1.1700	1.3433	2.1533
35/1w	-0.2500	-0.2267	0.0000	0.2300	0.2500	0.5367	0.6000	0.9433	1.1167	1.9267
45/1w	-0.4800	-0.4567	-0.2300	0.0000	0.0200	0.3067	0.3700	0.7133	0.8867	1.6967
35/1wo	-0.5000	-0.4767	-0.2500	-0.0200	0.0000	0.2867	0.3500	0.6933	0.8667	1.6767
25/1wo	-0.7867	-0.7633	-0.5367	-0.3067	-0.2867	0.0000	0.0633	0.4067	0.5800	1.3900
25/1w	-0.8500	-0.8267	-0.6000	-0.3700	-0.3500	-0.0633	0.0000	0.3433	0.5167	1.3267
55/1wo	-1.1933	-1.1700	-0.9433	-0.7133	-0.6933	-0.4067	-0.3433	0.0000	0.1733	0.9833
15/1wo	-1.3667	-1.3433	-1.1167	-0.8867	-0.8667	-0.5800	-0.5167	-0.1733	0.0000	0.8100
15/1w	-2.1767	-2.1533	-1.9267	-1.6967	-1.6767	-1.3900	-1.3267	-0.9833	-0.8100	0.0000

Alpha=0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.54110	0.05

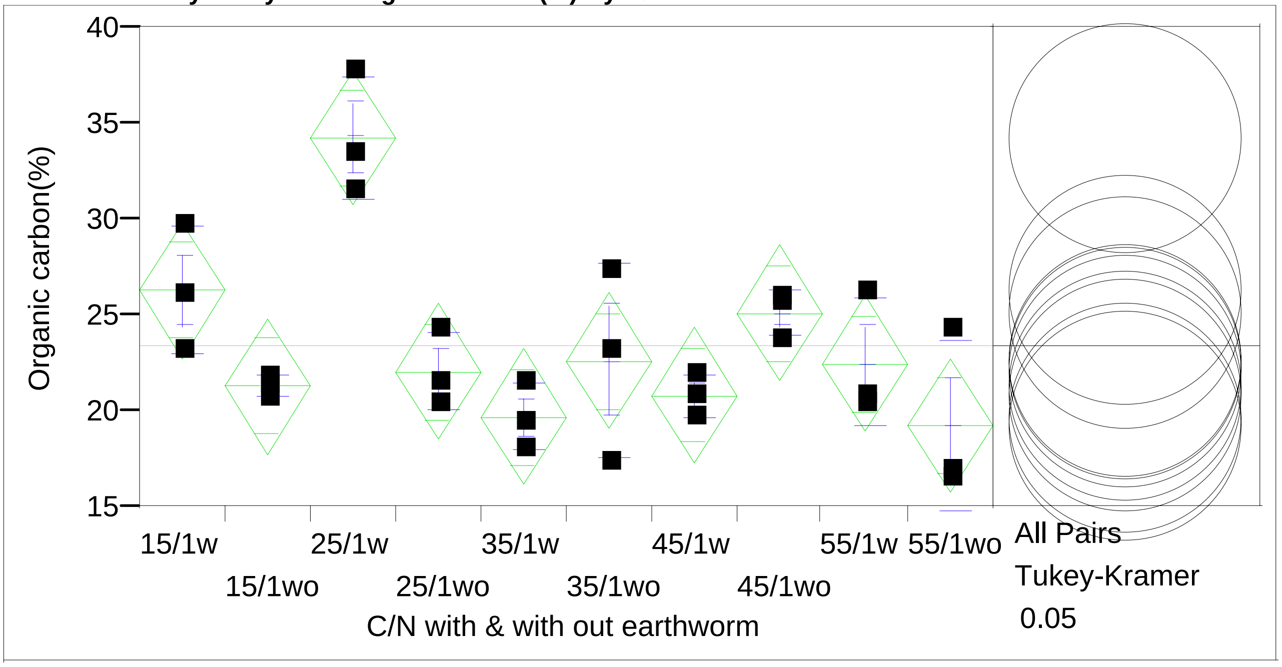
Abs(Dif)-LSD	55/1w	45/1wo	35/1w	45/1w	35/1wo	25/1wo	25/1w	55/1wo	15/1wo	15/1w
55/1w	-1.3527	-1.3294	-1.1027	-0.8727	-0.8527	-0.5660	-0.5027	-0.1594	0.0140	0.8240
45/1wo	-1.3294	-1.3527	-1.1260	-0.8960	-0.8760	-0.5894	-0.5260	-0.1827	-0.0094	0.8006
35/1w	-1.1027	-1.1260	-1.3527	-1.1227	-1.1027	-0.8160	-0.7527	-0.4094	-0.2360	0.5740
45/1w	-0.8727	-0.8960	-1.1227	-1.3527	-1.3327	-1.0460	-0.9827	-0.6394	-0.4660	0.3440
35/1wo	-0.8527	-0.8760	-1.1027	-1.3327	-1.3527	-1.0660	-1.0027	-0.6594	-0.4860	0.3240
25/1wo	-0.5660	-0.5894	-0.8160	-1.0460	-1.0660	-1.3527	-1.2894	-0.9460	-0.7727	0.0373
25/1w	-0.5027	-0.5260	-0.7527	-0.9827	-1.0027	-1.2894	-1.3527	-1.0094	-0.8360	-0.0260
55/1wo	-0.1594	-0.1827	-0.4094	-0.6394	-0.6594	-0.9460	-1.0094	-1.3527	-1.1794	-0.3694
15/1wo	0.0140	-0.0094	-0.2360	-0.4660	-0.4860	-0.7727	-0.8360	-1.1794	-1.3527	-0.5427
15/1w	0.8240	0.8006	0.5740	0.3440	0.3240	0.0373	-0.0260	-0.3694	-0.5427	-1.3527

Positive values show pairs of means that are significantly different.

Level				Mean
55/1w	A			7.8233333
45/1wo	A	B		7.8000000
35/1w	A	B		7.5733333
45/1w	A	B		7.3433333
35/1wo	A	B		7.3233333
25/1wo	A	B		7.0366667
25/1w	A	B	C	6.9733333
55/1wo	A	B	C	6.6300000
15/1wo		B	C	6.4566667
15/1w			C	5.6466667

Levels not connected by same letter are significantly different

Table 2. Oneway Analysis of Organic carbon(%) By C/N with & with out earthworm



Oneway Anova

Summary of Fit

Rsquare	0.752413
Adj Rsquare	0.640999
Root Mean Square Error	2.93076
Mean of Response	23.38567
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C/N with & with out earthworm	9	522.05780	58.0064	6.7533	0.0002
Error	20	171.78713	8.5894		
C. Total	29	693.84494			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15/1w	3	26.2767	1.6921	22.747	29.806
15/1wo	3	21.2900	1.6921	17.760	24.820
25/1w	3	34.2267	1.6921	30.697	37.756
25/1wo	3	22.0767	1.6921	18.547	25.606
35/1w	3	19.6700	1.6921	16.140	23.200
35/1wo	3	22.6300	1.6921	19.100	26.160
45/1w	3	20.8300	1.6921	17.300	24.360
45/1wo	3	25.1333	1.6921	21.604	28.663
55/1w	3	22.4933	1.6921	18.964	26.023
55/1wo	3	19.2300	1.6921	15.700	22.760

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
15/1w	3	26.2767	3.24703	1.8747	18.211	34.343
15/1wo	3	21.2900	0.56045	0.3236	19.898	22.682
25/1w	3	34.2267	3.18073	1.8364	26.325	42.128
25/1wo	3	22.0767	2.00385	1.1569	17.099	27.055
35/1w	3	19.6700	1.74640	1.0083	15.332	24.008
35/1wo	3	22.6300	5.02346	2.9003	10.151	35.109
45/1w	3	20.8300	1.11000	0.6409	18.073	23.587
45/1wo	3	25.1333	1.21476	0.7013	22.116	28.151
55/1w	3	22.4933	3.25150	1.8773	14.416	30.570
55/1wo	3	19.2300	4.39758	2.5389	8.306	30.154

Means Comparisons

Dif=Mean[i]-Mean[j]	25/1w	15/1w	45/1wo	35/1wo	55/1w	25/1wo	15/1wo	45/1w	35/1w	55/1wo
25/1w	0.000	7.950	9.093	11.597	11.733	12.150	12.937	13.397	14.557	14.997
15/1w	-7.950	0.000	1.143	3.647	3.783	4.200	4.987	5.447	6.607	7.047
45/1wo	-9.093	-1.143	0.000	2.503	2.640	3.057	3.843	4.303	5.463	5.903
35/1wo	-11.597	-3.647	-2.503	0.000	0.137	0.553	1.340	1.800	2.960	3.400
55/1w	-11.733	-3.783	-2.640	-0.137	0.000	0.417	1.203	1.663	2.823	3.263
25/1wo	-12.150	-4.200	-3.057	-0.553	-0.417	0.000	0.787	1.247	2.407	2.847
15/1wo	-12.937	-4.987	-3.843	-1.340	-1.203	-0.787	0.000	0.460	1.620	2.060
45/1w	-13.397	-5.447	-4.303	-1.800	-1.663	-1.247	-0.460	0.000	1.160	1.600
35/1w	-14.557	-6.607	-5.463	-2.960	-2.823	-2.407	-1.620	-1.160	0.000	0.440
55/1wo	-14.997	-7.047	-5.903	-3.400	-3.263	-2.847	-2.060	-1.600	-0.440	0.000

Alpha=0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.54110	0.05

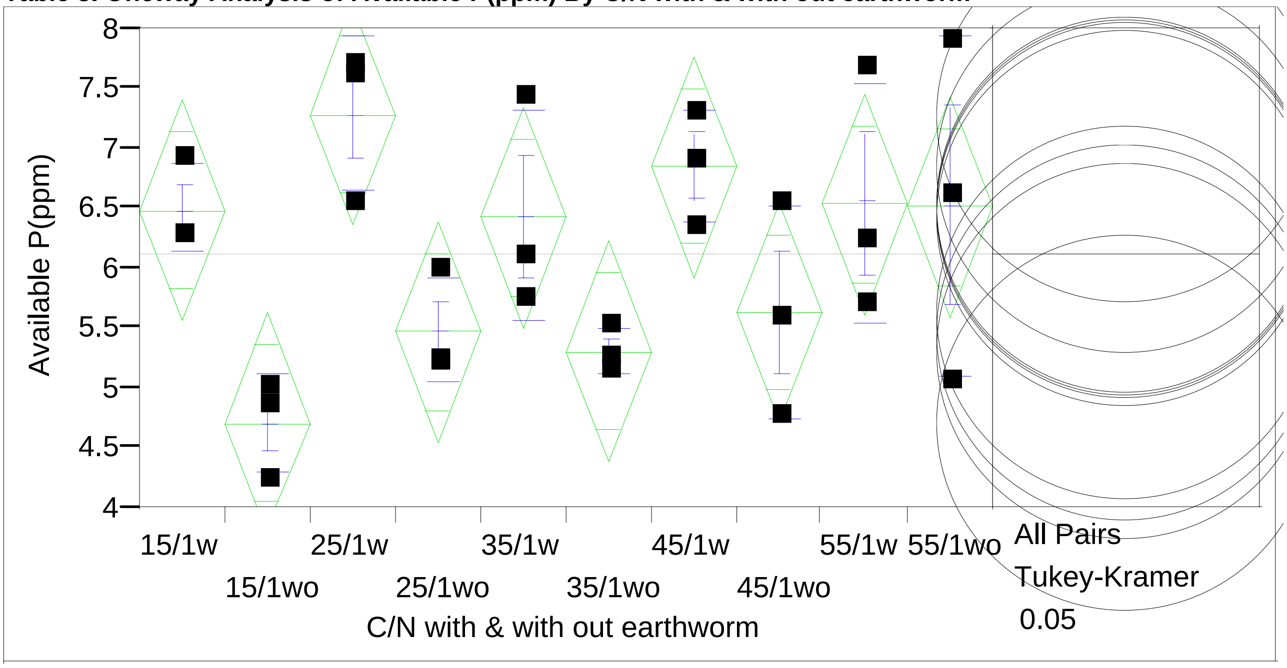
Abs(Dif)-LSD	25/1w	15/1w	45/1wo	35/1wo	55/1w	25/1wo	15/1wo	45/1w	35/1w	55/1wo
25/1w	-8.4737	-0.5237	0.6196	3.1230	3.2596	3.6763	4.4630	4.9230	6.0830	6.5230
15/1w	-0.5237	-8.4737	-7.3304	-4.8270	-4.6904	-4.2737	-3.4870	-3.0270	-1.8670	-1.4270
45/1wo	0.6196	-7.3304	-8.4737	-5.9704	-5.8337	-5.4170	-4.6304	-4.1704	-3.0104	-2.5704
35/1wo	3.1230	-4.8270	-5.9704	-8.4737	-8.3370	-7.9204	-7.1337	-6.6737	-5.5137	-5.0737
55/1w	3.2596	-4.6904	-5.8337	-8.3370	-8.4737	-8.0570	-7.2704	-6.8104	-5.6504	-5.2104
25/1wo	3.6763	-4.2737	-5.4170	-7.9204	-8.0570	-8.4737	-7.6870	-7.2270	-6.0670	-5.6270
15/1wo	4.4630	-3.4870	-4.6304	-7.1337	-7.2704	-7.6870	-8.4737	-8.0137	-6.8537	-6.4137
45/1w	4.9230	-3.0270	-4.1704	-6.6737	-6.8104	-7.2270	-8.0137	-8.4737	-7.3137	-6.8737
35/1w	6.0830	-1.8670	-3.0104	-5.5137	-5.6504	-6.0670	-6.8537	-7.3137	-8.4737	-8.0337
55/1wo	6.5230	-1.4270	-2.5704	-5.0737	-5.2104	-5.6270	-6.4137	-6.8737	-8.0337	-8.4737

Positive values show pairs of means that are significantly different.

Level			Mean
25/1w	A		34.226667
15/1w	A	B	26.276667
45/1wo		B	25.133333
35/1wo		B	22.630000
55/1w		B	22.493333
25/1wo		B	22.076667
15/1wo		B	21.290000
45/1w		B	20.830000
35/1w		B	19.670000
55/1wo		B	19.230000

Levels not connected by same letter are significantly different

Table 3. Oneway Analysis of Available P(ppm) By C/N with & with out earthworm



Oneway Anova

Summary of Fit

Rsquare	0.597052
Adj Rsquare	0.415726
Root Mean Square Error	0.764205
Mean of Response	6.122
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C/N with & with out earthworm	9	17.306680	1.92296	3.2927	0.0127
Error	20	11.680200	0.58401		
C. Total	29	28.986880			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15/1w	3	6.48667	0.44121	5.5663	7.4070
15/1wo	3	4.70667	0.44121	3.7863	5.6270
25/1w	3	7.28333	0.44121	6.3630	8.2037
25/1wo	3	5.47000	0.44121	4.5496	6.3904
35/1w	3	6.42667	0.44121	5.5063	7.3470
35/1wo	3	5.30667	0.44121	4.3863	6.2270
45/1w	3	6.85333	0.44121	5.9330	7.7737
45/1wo	3	5.63333	0.44121	4.7130	6.5537
55/1w	3	6.53667	0.44121	5.6163	7.4570
55/1wo	3	6.51667	0.44121	5.5963	7.4370

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
15/1w	3	6.48667	0.37528	0.21667	5.5544	7.419
15/1wo	3	4.70667	0.41199	0.23786	3.6832	5.730
25/1w	3	7.28333	0.63705	0.36780	5.7008	8.866
25/1wo	3	5.47000	0.44193	0.25515	4.3722	6.568
35/1w	3	6.42667	0.88839	0.51291	4.2198	8.634
35/1wo	3	5.30667	0.19140	0.11050	4.8312	5.782
45/1w	3	6.85333	0.47753	0.27570	5.6671	8.040
45/1wo	3	5.63333	0.89579	0.51718	3.4081	7.859
55/1w	3	6.53667	1.01796	0.58772	4.0079	9.065
55/1wo	3	6.51667	1.42683	0.82378	2.9722	10.061

Means Comparisons

Dif=Mean[i]-Mean[j]	25/1w	45/1w	55/1w	55/1wo	15/1w	35/1w	45/1wo	25/1wo	35/1wo	15/1wo
25/1w	0.0000	0.4300	0.7467	0.7667	0.7967	0.8567	1.6500	1.8133	1.9767	2.5767
45/1w	-0.4300	0.0000	0.3167	0.3367	0.3667	0.4267	1.2200	1.3833	1.5467	2.1467
55/1w	-0.7467	-0.3167	0.0000	0.0200	0.0500	0.1100	0.9033	1.0667	1.2300	1.8300
55/1wo	-0.7667	-0.3367	-0.0200	0.0000	0.0300	0.0900	0.8833	1.0467	1.2100	1.8100
15/1w	-0.7967	-0.3667	-0.0500	-0.0300	0.0000	0.0600	0.8533	1.0167	1.1800	1.7800
35/1w	-0.8567	-0.4267	-0.1100	-0.0900	-0.0600	0.0000	0.7933	0.9567	1.1200	1.7200
45/1wo	-1.6500	-1.2200	-0.9033	-0.8833	-0.8533	-0.7933	0.0000	0.1633	0.3267	0.9267
25/1wo	-1.8133	-1.3833	-1.0667	-1.0467	-1.0167	-0.9567	-0.1633	0.0000	0.1633	0.7633
35/1wo	-1.9767	-1.5467	-1.2300	-1.2100	-1.1800	-1.1200	-0.3267	-0.1633	0.0000	0.6000
15/1wo	-2.5767	-2.1467	-1.8300	-1.8100	-1.7800	-1.7200	-0.9267	-0.7633	-0.6000	0.0000

Alpha=0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.54110	0.05

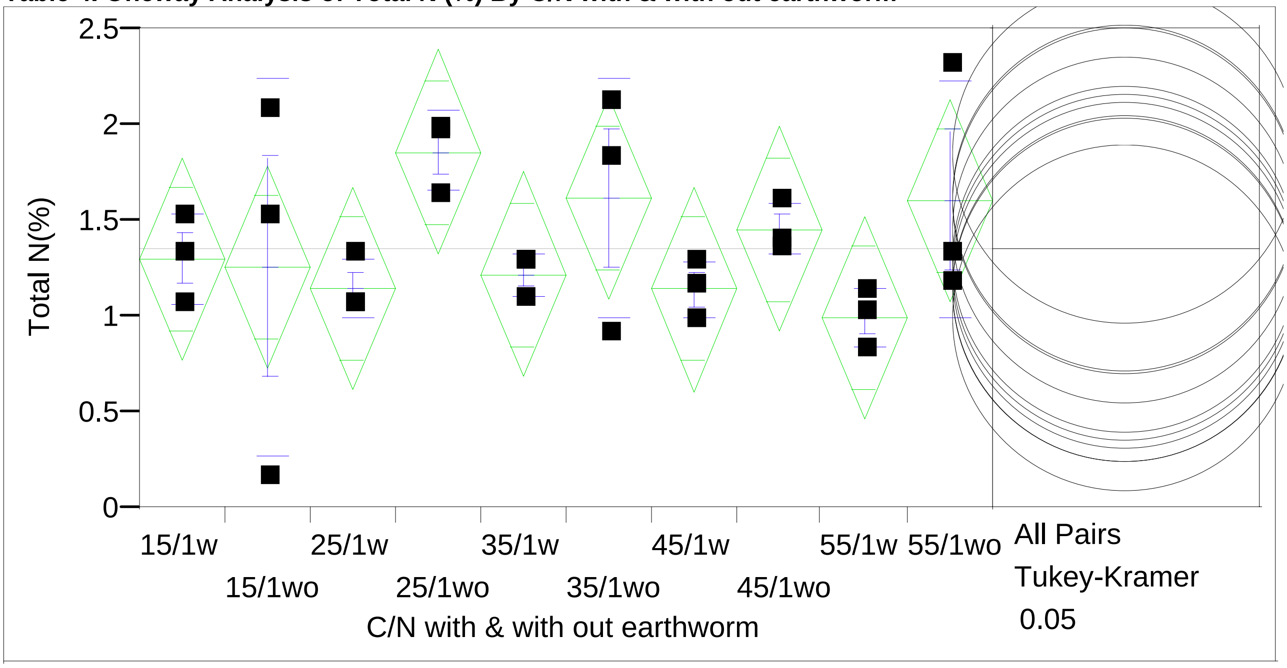
Abs(Dif)-LSD	25/1w	45/1w	55/1w	55/1wo	15/1w	35/1w	45/1wo	25/1wo	35/1wo	15/1wo
25/1w	-2.2095	-1.7795	-1.4629	-1.4429	-1.4129	-1.3529	-0.5595	-0.3962	-0.2329	0.3671
45/1w	-1.7795	-2.2095	-1.8929	-1.8729	-1.8429	-1.7829	-0.9895	-0.8262	-0.6629	-0.0629
55/1w	-1.4629	-1.8929	-2.2095	-2.1895	-2.1595	-2.0995	-1.3062	-1.1429	-0.9795	-0.3795
55/1wo	-1.4429	-1.8729	-2.1895	-2.2095	-2.1795	-2.1195	-1.3262	-1.1629	-0.9995	-0.3995
15/1w	-1.4129	-1.8429	-2.1595	-2.1795	-2.2095	-2.1495	-1.3562	-1.1929	-1.0295	-0.4295
35/1w	-1.3529	-1.7829	-2.0995	-2.1195	-2.1495	-2.2095	-1.4162	-1.2529	-1.0895	-0.4895
45/1wo	-0.5595	-0.9895	-1.3062	-1.3262	-1.3562	-1.4162	-2.2095	-2.0462	-1.8829	-1.2829
25/1wo	-0.3962	-0.8262	-1.1429	-1.1629	-1.1929	-1.2529	-2.0462	-2.2095	-2.0462	-1.4462
35/1wo	-0.2329	-0.6629	-0.9795	-0.9995	-1.0295	-1.0895	-1.8829	-2.0462	-2.2095	-1.6095
15/1wo	0.3671	-0.0629	-0.3795	-0.3995	-0.4295	-0.4895	-1.2829	-1.4462	-1.6095	-2.2095

Positive values show pairs of means that are significantly different.

Level			Mean
25/1w	A		7.2833333
45/1w	A	B	6.8533333
55/1w	A	B	6.5366667
55/1wo	A	B	6.5166667
15/1w	A	B	6.4866667
35/1w	A	B	6.4266667
45/1wo	A	B	5.6333333
25/1wo	A	B	5.4700000
35/1wo	A	B	5.3066667
15/1wo		B	4.7066667

Levels not connected by same letter are significantly different

Table 4. Oneway Analysis of Total N (%) By C/N with & with out earthworm



Oneway Anova

Summary of Fit

Rsquare	0.333181
Adj Rsquare	0.033113
Root Mean Square Error	0.44084
Mean of Response	1.359
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C/N with & with out earthworm	9	1.9420700	0.215786	1.1104	0.3995
Error	20	3.8868000	0.194340		
C. Total	29	5.8288700			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15/1w	3	1.30000	0.25452	0.7691	1.8309
15/1wo	3	1.25333	0.25452	0.7224	1.7843
25/1w	3	1.14667	0.25452	0.6157	1.6776
25/1wo	3	1.86000	0.25452	1.3291	2.3909
35/1w	3	1.22000	0.25452	0.6891	1.7509
35/1wo	3	1.61667	0.25452	1.0857	2.1476
45/1w	3	1.14000	0.25452	0.6091	1.6709
45/1wo	3	1.45667	0.25452	0.9257	1.9876
55/1w	3	0.99333	0.25452	0.4624	1.5243
55/1wo	3	1.60333	0.25452	1.0724	2.1343

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
15/1w	3	1.30000	0.230651	0.13317	0.727	1.8730
15/1wo	3	1.25333	0.987387	0.57007	-1.199	3.7061
25/1w	3	1.14667	0.150111	0.08667	0.774	1.5196
25/1wo	3	1.86000	0.199249	0.11504	1.365	2.3550
35/1w	3	1.22000	0.112694	0.06506	0.940	1.4999
35/1wo	3	1.61667	0.630106	0.36379	0.051	3.1819
45/1w	3	1.14000	0.150997	0.08718	0.765	1.5151
45/1wo	3	1.45667	0.134288	0.07753	1.123	1.7903
55/1w	3	0.99333	0.151767	0.08762	0.616	1.3703
55/1wo	3	1.60333	0.615982	0.35564	0.073	3.1335

Means Comparisons

Dif=Mean[i]-Mean[j]	25/1wo	35/1wo	55/1wo	45/1wo	15/1w	15/1wo	35/1w	25/1w	45/1w	55/1w
25/1wo	0.00000	0.24333	0.25667	0.40333	0.56000	0.60667	0.64000	0.71333	0.72000	0.86667
35/1wo	-0.24333	0.00000	0.01333	0.16000	0.31667	0.36333	0.39667	0.47000	0.47667	0.62333
55/1wo	-0.25667	-0.01333	0.00000	0.14667	0.30333	0.35000	0.38333	0.45667	0.46333	0.61000
45/1wo	-0.40333	-0.16000	-0.14667	0.00000	0.15667	0.20333	0.23667	0.31000	0.31667	0.46333
15/1w	-0.56000	-0.31667	-0.30333	-0.15667	0.00000	0.04667	0.08000	0.15333	0.16000	0.30667
15/1wo	-0.60667	-0.36333	-0.35000	-0.20333	-0.04667	0.00000	0.03333	0.10667	0.11333	0.26000
35/1w	-0.64000	-0.39667	-0.38333	-0.23667	-0.08000	-0.03333	0.00000	0.07333	0.08000	0.22667
25/1w	-0.71333	-0.47000	-0.45667	-0.31000	-0.15333	-0.10667	-0.07333	0.00000	0.00667	0.15333
45/1w	-0.72000	-0.47667	-0.46333	-0.31667	-0.16000	-0.11333	-0.08000	-0.00667	0.00000	0.14667
55/1w	-0.86667	-0.62333	-0.61000	-0.46333	-0.30667	-0.26000	-0.22667	-0.15333	-0.14667	0.00000

Alpha=0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.54110	0.05

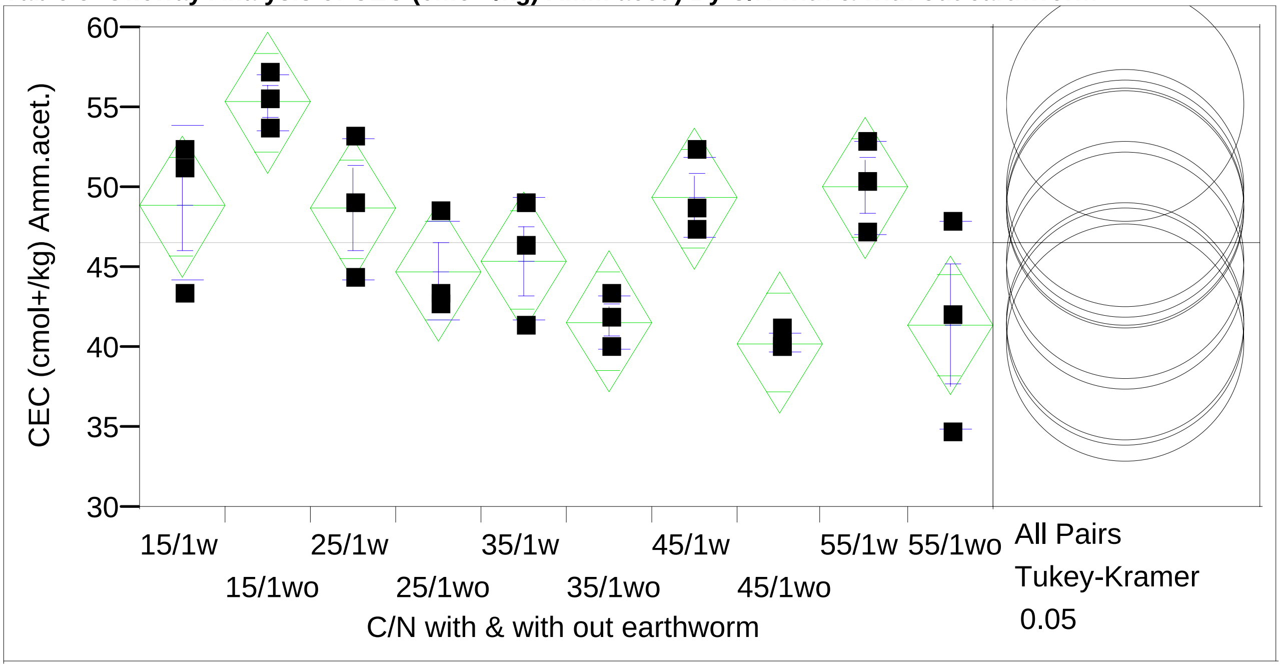
Abs(Dif)-LSD	25/1wo	35/1wo	55/1wo	45/1wo	15/1w	15/1wo	35/1w	25/1w	45/1w	55/1w
25/1wo	-1.2746	-1.0313	-1.0179	-0.8713	-0.7146	-0.6679	-0.6346	-0.5613	-0.5546	-0.4079
35/1wo	-1.0313	-1.2746	-1.2613	-1.1146	-0.9579	-0.9113	-0.8779	-0.8046	-0.7979	-0.6513
55/1wo	-1.0179	-1.2613	-1.2746	-1.1279	-0.9713	-0.9246	-0.8913	-0.8179	-0.8113	-0.6646
45/1wo	-0.8713	-1.1146	-1.1279	-1.2746	-1.1179	-1.0713	-1.0379	-0.9646	-0.9579	-0.8113
15/1w	-0.7146	-0.9579	-0.9713	-1.1179	-1.2746	-1.2279	-1.1946	-1.1213	-1.1146	-0.9679
15/1wo	-0.6679	-0.9113	-0.9246	-1.0713	-1.2279	-1.2746	-1.2413	-1.1679	-1.1613	-1.0146
35/1w	-0.6346	-0.8779	-0.8913	-1.0379	-1.1946	-1.2413	-1.2746	-1.2013	-1.1946	-1.0479
25/1w	-0.5613	-0.8046	-0.8179	-0.9646	-1.1213	-1.1679	-1.2013	-1.2746	-1.2679	-1.1213
45/1w	-0.5546	-0.7979	-0.8113	-0.9579	-1.1146	-1.1613	-1.1946	-1.2679	-1.2746	-1.1279
55/1w	-0.4079	-0.6513	-0.6646	-0.8113	-0.9679	-1.0146	-1.0479	-1.1213	-1.1279	-1.2746

Positive values show pairs of means that are significantly different.

Level		Mean
25/1wo	A	1.8600000
35/1wo	A	1.6166667
55/1wo	A	1.6033333
45/1wo	A	1.4566667
15/1w	A	1.3000000
15/1wo	A	1.2533333
35/1w	A	1.2200000
25/1w	A	1.1466667
45/1w	A	1.1400000
55/1w	A	0.9933333

Levels not connected by same letter are significantly different

Table 5. Oneway Analysis of CEC (cmol+/kg) Amm.acet.) By C/N with & with out earthworm



Oneway Anova

Summary of Fit

Rsquare	0.695662
Adj Rsquare	0.558709
Root Mean Square Error	3.630035
Mean of Response	46.58733
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C/N with & with out earthworm	9	602.41125	66.9346	5.0796	0.0012
Error	20	263.54313	13.1772		
C. Total	29	865.95439			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15/1w	3	48.8400	2.0958	44.468	53.212
15/1wo	3	55.3533	2.0958	50.982	59.725
25/1w	3	48.6967	2.0958	44.325	53.068
25/1wo	3	44.7700	2.0958	40.398	49.142
35/1w	3	45.4367	2.0958	41.065	49.808
35/1wo	3	41.6600	2.0958	37.288	46.032
45/1w	3	49.3633	2.0958	44.992	53.735
45/1wo	3	40.3233	2.0958	35.952	44.695
55/1w	3	50.0200	2.0958	45.648	54.392
55/1wo	3	41.4100	2.0958	37.038	45.782

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
15/1w	3	48.8400	4.83838	2.7934	36.821	60.859
15/1wo	3	55.3533	1.77455	1.0245	50.945	59.762
25/1w	3	48.6967	4.43674	2.5616	37.675	59.718
25/1wo	3	44.7700	3.16147	1.8253	36.916	52.624
35/1w	3	45.4367	3.82312	2.2073	35.940	54.934
35/1wo	3	41.6600	1.66610	0.9619	37.521	45.799
45/1w	3	49.3633	2.51866	1.4541	43.107	55.620
45/1wo	3	40.3233	0.62931	0.3633	38.760	41.887
55/1w	3	50.0200	2.88792	1.6673	42.846	57.194
55/1wo	3	41.4100	6.56210	3.7886	25.109	57.711

Means Comparisons

Dif=Mean[i]-Mean[j]	15/1wo	55/1w	45/1w	15/1w	25/1w	35/1w	25/1wo	35/1wo	55/1wo	45/1wo
15/1wo	0.000	5.333	5.990	6.513	6.657	9.917	10.583	13.693	13.943	15.030
55/1w	-5.333	0.000	0.657	1.180	1.323	4.583	5.250	8.360	8.610	9.697
45/1w	-5.990	-0.657	0.000	0.523	0.667	3.927	4.593	7.703	7.953	9.040
15/1w	-6.513	-1.180	-0.523	0.000	0.143	3.403	4.070	7.180	7.430	8.517
25/1w	-6.657	-1.323	-0.667	-0.143	0.000	3.260	3.927	7.037	7.287	8.373
35/1w	-9.917	-4.583	-3.927	-3.403	-3.260	0.000	0.667	3.777	4.027	5.113
25/1wo	-10.583	-5.250	-4.593	-4.070	-3.927	-0.667	0.000	3.110	3.360	4.447
35/1wo	-13.693	-8.360	-7.703	-7.180	-7.037	-3.777	-3.110	0.000	0.250	1.337
55/1wo	-13.943	-8.610	-7.953	-7.430	-7.287	-4.027	-3.360	-0.250	0.000	1.087
45/1wo	-15.030	-9.697	-9.040	-8.517	-8.373	-5.113	-4.447	-1.337	-1.087	0.000

Alpha=0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.54110	0.05

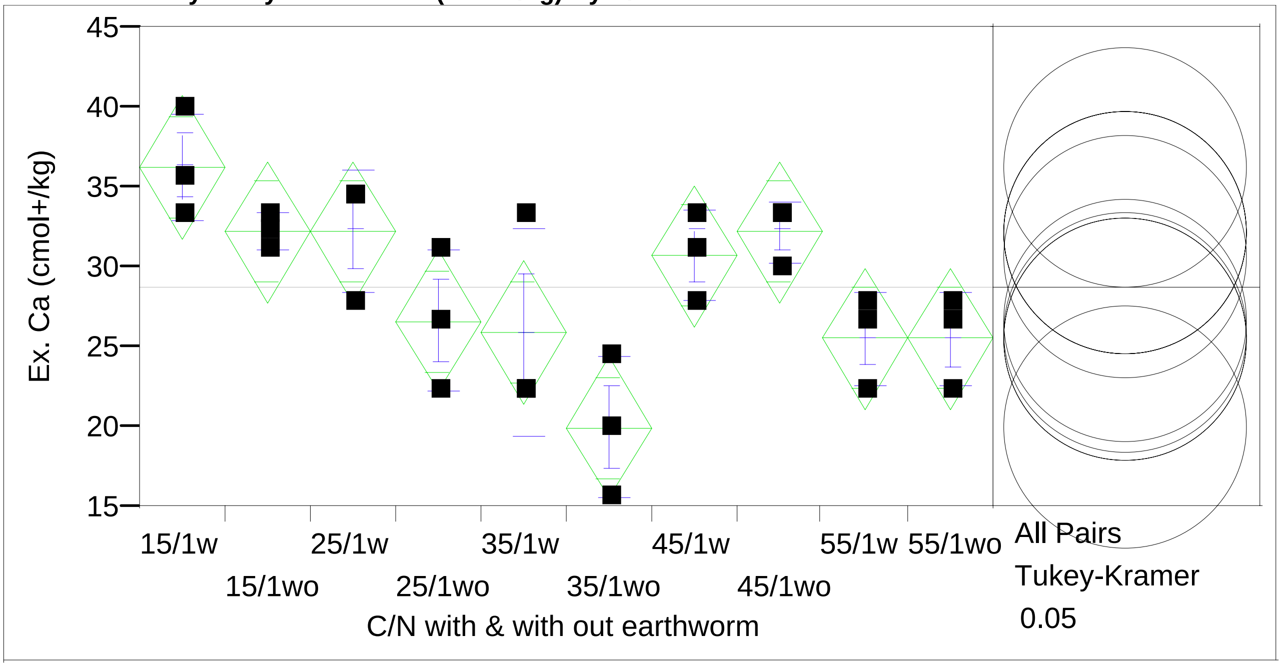
Abs(Dif)-LSD	15/1wo	55/1w	45/1w	15/1w	25/1w	35/1w	25/1wo	35/1wo	55/1wo	45/1wo
15/1wo	-10.496	-5.162	-4.506	-3.982	-3.839	-0.579	0.088	3.198	3.448	4.534
55/1w	-5.162	-10.496	-9.839	-9.316	-9.172	-5.912	-5.246	-2.136	-1.886	-0.799
45/1w	-4.506	-9.839	-10.496	-9.972	-9.829	-6.569	-5.902	-2.792	-2.542	-1.456
15/1w	-3.982	-9.316	-9.972	-10.496	-10.352	-7.092	-6.426	-3.316	-3.066	-1.979
25/1w	-3.839	-9.172	-9.829	-10.352	-10.496	-7.236	-6.569	-3.459	-3.209	-2.122
35/1w	-0.579	-5.912	-6.569	-7.092	-7.236	-10.496	-9.829	-6.719	-6.469	-5.382
25/1wo	0.088	-5.246	-5.902	-6.426	-6.569	-9.829	-10.496	-7.386	-7.136	-6.049
35/1wo	3.198	-2.136	-2.792	-3.316	-3.459	-6.719	-7.386	-10.496	-10.246	-9.159
55/1wo	3.448	-1.886	-2.542	-3.066	-3.209	-6.469	-7.136	-10.246	-10.496	-9.409
45/1wo	4.534	-0.799	-1.456	-1.979	-2.122	-5.382	-6.049	-9.159	-9.409	-10.496

Positive values show pairs of means that are significantly different.

Level			Mean
15/1wo	A		55.353333
55/1w	A	B	50.020000
45/1w	A	B	49.363333
15/1w	A	B	48.840000
25/1w	A	B	48.696667
35/1w	A	B	45.436667
25/1wo		B	44.770000
35/1wo		B	41.660000
55/1wo		B	41.410000
45/1wo		B	40.323333

Levels not connected by same letter are significantly different

Table 6. Oneway Analysis of Ex. Ca (cmol+/kg) By C/N with & with out earthworm



Oneway Anova
Summary of Fit

Rsquare	0.693209
Adj Rsquare	0.555153
Root Mean Square Error	3.697552
Mean of Response	28.71067
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C/N with & with out earthworm	9	617.84539	68.6495	5.0212	0.0013
Error	20	273.43780	13.6719		
C. Total	29	891.28319			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15/1w	3	36.2600	2.1348	31.807	40.713
15/1wo	3	32.1867	2.1348	27.734	36.640
25/1w	3	32.1867	2.1348	27.734	36.640
25/1wo	3	26.6400	2.1348	22.187	31.093
35/1w	3	25.9000	2.1348	21.447	30.353
35/1wo	3	19.9800	2.1348	15.527	24.433
45/1w	3	30.7100	2.1348	26.257	35.163
45/1wo	3	32.1900	2.1348	27.737	36.643
55/1w	3	25.5300	2.1348	21.077	29.983
55/1wo	3	25.5233	2.1348	21.070	29.976

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
15/1w	3	36.2600	3.39111	1.9579	27.836	44.684
15/1wo	3	32.1867	1.11002	0.6409	29.429	34.944
25/1w	3	32.1867	3.84227	2.2183	22.642	41.731
25/1wo	3	26.6400	4.44000	2.5634	15.610	37.670
35/1w	3	25.9000	6.40859	3.7000	9.980	41.820
35/1wo	3	19.9800	4.44000	2.5634	8.950	31.010
45/1w	3	30.7100	2.79344	1.6128	23.771	37.649
45/1wo	3	32.1900	1.92258	1.1100	27.414	36.966
55/1w	3	25.5300	2.93678	1.6956	18.235	32.825
55/1wo	3	25.5233	2.93302	1.6934	18.237	32.809

Means Comparisons

Dif=Mean[i]-Mean[j]	15/1w	45/1wo	15/1wo	25/1w	45/1w	25/1wo	35/1w	55/1w	55/1wo	35/1wo
15/1w	0.000	4.070	4.073	4.073	5.550	9.620	10.360	10.730	10.737	16.280
45/1wo	-4.070	0.000	0.003	0.003	1.480	5.550	6.290	6.660	6.667	12.210
15/1wo	-4.073	-0.003	0.000	0.000	1.477	5.547	6.287	6.657	6.663	12.207
25/1w	-4.073	-0.003	0.000	0.000	1.477	5.547	6.287	6.657	6.663	12.207
45/1w	-5.550	-1.480	-1.477	-1.477	0.000	4.070	4.810	5.180	5.187	10.730
25/1wo	-9.620	-5.550	-5.547	-5.547	-4.070	0.000	0.740	1.110	1.117	6.660
35/1w	-10.360	-6.290	-6.287	-6.287	-4.810	-0.740	0.000	0.370	0.377	5.920
55/1w	-10.730	-6.660	-6.657	-6.657	-5.180	-1.110	-0.370	0.000	0.007	5.550
55/1wo	-10.737	-6.667	-6.663	-6.663	-5.187	-1.117	-0.377	-0.007	0.000	5.543
35/1wo	-16.280	-12.210	-12.207	-12.207	-10.730	-6.660	-5.920	-5.550	-5.543	0.000

Alpha=0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.54110	0.05

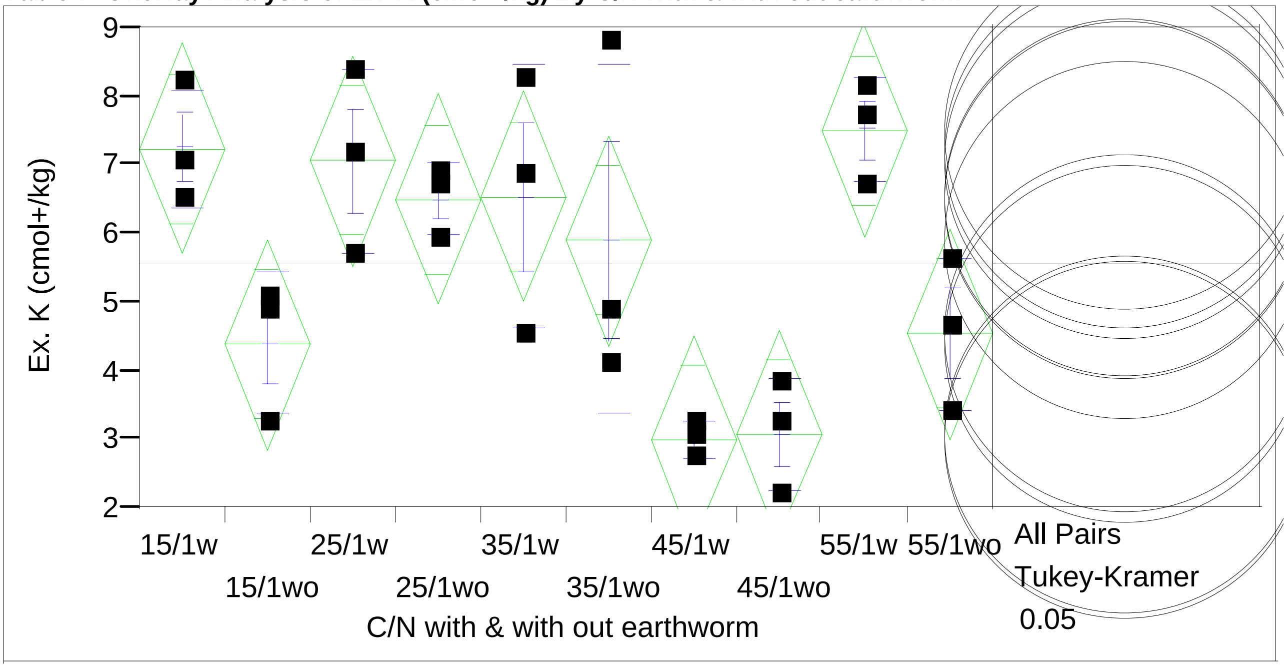
Abs(Dif)-LSD	15/1w	45/1wo	15/1wo	25/1w	45/1w	25/1wo	35/1w	55/1w	55/1wo	35/1wo
15/1w	-10.691	-6.621	-6.617	-6.617	-5.141	-1.071	-0.331	0.039	0.046	5.589
45/1wo	-6.621	-10.691	-10.687	-10.687	-9.211	-5.141	-4.401	-4.031	-4.024	1.519
15/1wo	-6.617	-10.687	-10.691	-10.691	-9.214	-5.144	-4.404	-4.034	-4.027	1.516
25/1w	-6.617	-10.687	-10.691	-10.691	-9.214	-5.144	-4.404	-4.034	-4.027	1.516
45/1w	-5.141	-9.211	-9.214	-9.214	-10.691	-6.621	-5.881	-5.511	-5.504	0.039
25/1wo	-1.071	-5.141	-5.144	-5.144	-6.621	-10.691	-9.951	-9.581	-9.574	-4.031
35/1w	-0.331	-4.401	-4.404	-4.404	-5.881	-9.951	-10.691	-10.321	-10.314	-4.771
55/1w	0.039	-4.031	-4.034	-4.034	-5.511	-9.581	-10.321	-10.691	-10.684	-5.141
55/1wo	0.046	-4.024	-4.027	-4.027	-5.504	-9.574	-10.314	-10.684	-10.691	-5.147
35/1wo	5.589	1.519	1.516	1.516	0.039	-4.031	-4.771	-5.141	-5.147	-10.691

Positive values show pairs of means that are significantly different.

Level				Mean
15/1w	A			36.260000
45/1wo	A	B		32.190000
15/1wo	A	B		32.186667
25/1w	A	B		32.186667
45/1w	A	B		30.710000
25/1wo	A	B	C	26.640000
35/1w	A	B	C	25.900000
55/1w		B	C	25.530000
55/1wo		B	C	25.523333
35/1wo			C	19.980000

Levels not connected by same letter are significantly different

Table 7. Oneway Analysis of Ex. K (cmol+/kg) By C/N with & with out earthworm



Oneway Anova
Summary of Fit

Rsquare	0.705371
Adj Rsquare	0.572788
Root Mean Square Error	1.276192
Mean of Response	5.570333
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C/N with & with out earthworm	9	77.98376	8.66486	5.3202	0.0009
Error	20	32.57333	1.62867		
C. Total	29	110.55710			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15/1w	3	7.24333	0.73681	5.7064	8.7803
15/1wo	3	4.38333	0.73681	2.8464	5.9203
25/1w	3	7.06000	0.73681	5.5230	8.5970
25/1wo	3	6.49333	0.73681	4.9564	8.0303
35/1w	3	6.53667	0.73681	4.9997	8.0736
35/1wo	3	5.90000	0.73681	4.3630	7.4370
45/1w	3	2.99000	0.73681	1.4530	4.5270
45/1wo	3	3.06667	0.73681	1.5297	4.6036
55/1w	3	7.49000	0.73681	5.9530	9.0270
55/1wo	3	4.54000	0.73681	3.0030	6.0770

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
15/1w	3	7.24333	0.86008	0.4966	5.107	9.380
15/1wo	3	4.38333	1.01195	0.5842	1.870	6.897
25/1w	3	7.06000	1.33727	0.7721	3.738	10.382
25/1wo	3	6.49333	0.50461	0.2913	5.240	7.747
35/1w	3	6.53667	1.89579	1.0945	1.827	11.246
35/1wo	3	5.90000	2.52293	1.4566	-0.367	12.167
45/1w	3	2.99000	0.25865	0.1493	2.347	3.633
45/1wo	3	3.06667	0.82379	0.4756	1.020	5.113
55/1w	3	7.49000	0.73369	0.4236	5.667	9.313
55/1wo	3	4.54000	1.11216	0.6421	1.777	7.303

Means Comparisons

Dif=Mean[i]-Mean[j]	55/1w	15/1w	25/1w	35/1w	25/1wo	35/1wo	55/1wo	15/1wo	45/1wo	45/1w
55/1w	0.0000	0.2467	0.4300	0.9533	0.9967	1.5900	2.9500	3.1067	4.4233	4.5000
15/1w	-0.2467	0.0000	0.1833	0.7067	0.7500	1.3433	2.7033	2.8600	4.1767	4.2533
25/1w	-0.4300	-0.1833	0.0000	0.5233	0.5667	1.1600	2.5200	2.6767	3.9933	4.0700
35/1w	-0.9533	-0.7067	-0.5233	0.0000	0.0433	0.6367	1.9967	2.1533	3.4700	3.5467
25/1wo	-0.9967	-0.7500	-0.5667	-0.0433	0.0000	0.5933	1.9533	2.1100	3.4267	3.5033
35/1wo	-1.5900	-1.3433	-1.1600	-0.6367	-0.5933	0.0000	1.3600	1.5167	2.8333	2.9100
55/1wo	-2.9500	-2.7033	-2.5200	-1.9967	-1.9533	-1.3600	0.0000	0.1567	1.4733	1.5500
15/1wo	-3.1067	-2.8600	-2.6767	-2.1533	-2.1100	-1.5167	-0.1567	0.0000	1.3167	1.3933
45/1wo	-4.4233	-4.1767	-3.9933	-3.4700	-3.4267	-2.8333	-1.4733	-1.3167	0.0000	0.0767
45/1w	-4.5000	-4.2533	-4.0700	-3.5467	-3.5033	-2.9100	-1.5500	-1.3933	-0.0767	0.0000

Alpha=0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.54110	0.05

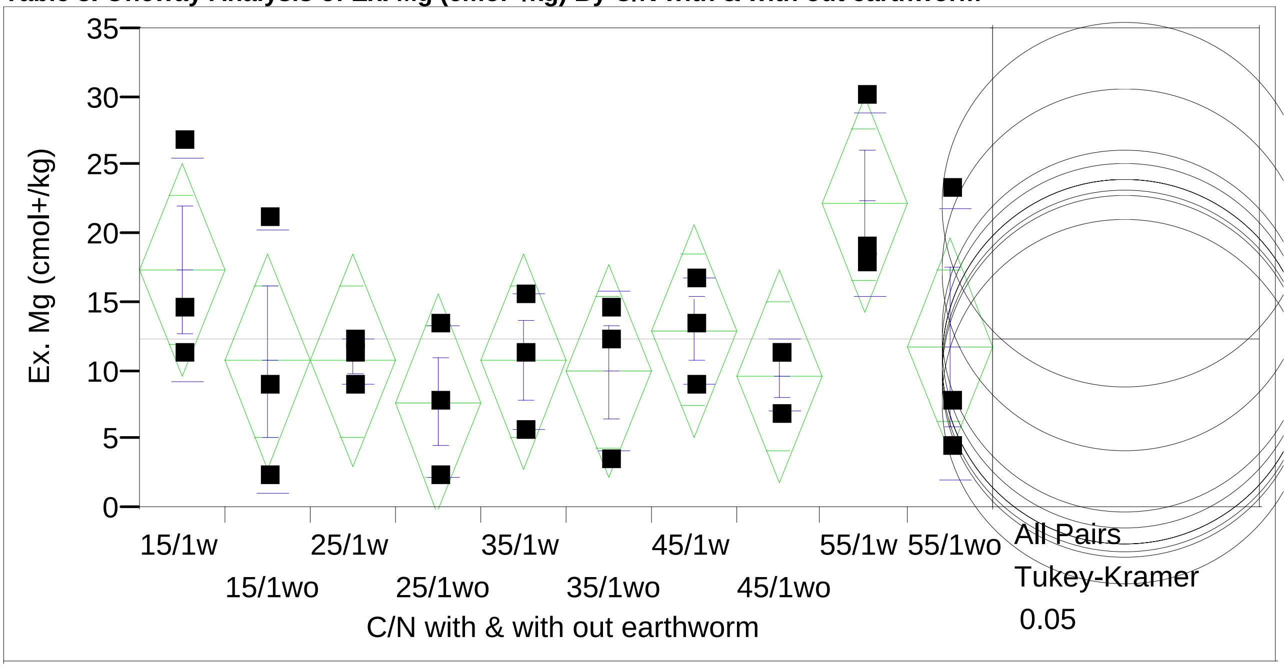
Abs(Dif)-LSD	55/1w	15/1w	25/1w	35/1w	25/1wo	35/1wo	55/1wo	15/1wo	45/1wo	45/1w
55/1w	-3.6898	-3.4432	-3.2598	-2.7365	-2.6932	-2.0998	-0.7398	-0.5832	0.7335	0.8102
15/1w	-3.4432	-3.6898	-3.5065	-2.9832	-2.9398	-2.3465	-0.9865	-0.8298	0.4868	0.5635
25/1w	-3.2598	-3.5065	-3.6898	-3.1665	-3.1232	-2.5298	-1.1698	-1.0132	0.3035	0.3802
35/1w	-2.7365	-2.9832	-3.1665	-3.6898	-3.6465	-3.0532	-1.6932	-1.5365	-0.2198	-0.1432
25/1wo	-2.6932	-2.9398	-3.1232	-3.6465	-3.6898	-3.0965	-1.7365	-1.5798	-0.2632	-0.1865
35/1wo	-2.0998	-2.3465	-2.5298	-3.0532	-3.0965	-3.6898	-2.3298	-2.1732	-0.8565	-0.7798
55/1wo	-0.7398	-0.9865	-1.1698	-1.6932	-1.7365	-2.3298	-3.6898	-3.5332	-2.2165	-2.1398
15/1wo	-0.5832	-0.8298	-1.0132	-1.5365	-1.5798	-2.1732	-3.5332	-3.6898	-2.3732	-2.2965
45/1wo	0.7335	0.4868	0.3035	-0.2198	-0.2632	-0.8565	-2.2165	-2.3732	-3.6898	-3.6132
45/1w	0.8102	0.5635	0.3802	-0.1432	-0.1865	-0.7798	-2.1398	-2.2965	-3.6132	-3.6898

Positive values show pairs of means that are significantly different.

Level			Mean
55/1w	A		7.4900000
15/1w	A		7.2433333
25/1w	A		7.0600000
35/1w	A	B	6.5366667
25/1wo	A	B	6.4933333
35/1wo	A	B	5.9000000
55/1wo	A	B	4.5400000
15/1wo	A	B	4.3833333
45/1wo		B	3.0666667
45/1w		B	2.9900000

Levels not connected by same letter are significantly different

Table 8. Oneway Analysis of Ex. Mg (cmol+/kg) By C/N with & with out earthworm



Oneway Anova
Summary of Fit

Rsquare	0.370287
Adj Rsquare	0.086917
Root Mean Square Error	6.489351
Mean of Response	12.39733
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C/N with & with out earthworm	9	495.2553	55.0284	1.3067	0.2938
Error	20	842.2335	42.1117		
C. Total	29	1337.4888			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15/1w	3	17.4100	3.7466	9.59	25.225
15/1wo	3	10.7300	3.7466	2.91	18.545
25/1w	3	10.7333	3.7466	2.92	18.549
25/1wo	3	7.7700	3.7466	-0.05	15.585
35/1w	3	10.7300	3.7466	2.91	18.545
35/1wo	3	9.9900	3.7466	2.17	17.805
45/1w	3	12.9500	3.7466	5.13	20.765
45/1wo	3	9.6200	3.7466	1.80	17.435
55/1w	3	22.2000	3.7466	14.38	30.015
55/1wo	3	11.8400	3.7466	4.02	19.655

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
15/1w	3	17.4100	8.2159	4.7434	-3.00	37.819
15/1wo	3	10.7300	9.5701	5.5253	-13.04	34.503
25/1w	3	10.7333	1.6967	0.9796	6.52	14.948
25/1wo	3	7.7700	5.5500	3.2043	-6.02	21.557
35/1w	3	10.7300	5.0053	2.8898	-1.70	23.164
35/1wo	3	9.9900	5.8736	3.3911	-4.60	24.581
45/1w	3	12.9500	3.8982	2.2506	3.27	22.634
45/1wo	3	9.6200	2.5634	1.4800	3.25	15.988
55/1w	3	22.2000	6.7519	3.8982	5.43	38.973
55/1wo	3	11.8400	10.0719	5.8150	-13.18	36.860

Means Comparisons

Dif=Mean[i]-Mean[j]	55/1w	15/1w	45/1w	55/1wo	25/1w	35/1w	15/1wo	35/1wo	45/1wo	25/1wo
55/1w	0.000	4.790	9.250	10.360	11.467	11.470	11.470	12.210	12.580	14.430
15/1w	-4.790	0.000	4.460	5.570	6.677	6.680	6.680	7.420	7.790	9.640
45/1w	-9.250	-4.460	0.000	1.110	2.217	2.220	2.220	2.960	3.330	5.180
55/1wo	-10.360	-5.570	-1.110	0.000	1.107	1.110	1.110	1.850	2.220	4.070
25/1w	-11.467	-6.677	-2.217	-1.107	0.000	0.003	0.003	0.743	1.113	2.963
35/1w	-11.470	-6.680	-2.220	-1.110	-0.003	0.000	0.000	0.740	1.110	2.960
15/1wo	-11.470	-6.680	-2.220	-1.110	-0.003	0.000	0.000	0.740	1.110	2.960
35/1wo	-12.210	-7.420	-2.960	-1.850	-0.743	-0.740	-0.740	0.000	0.370	2.220
45/1wo	-12.580	-7.790	-3.330	-2.220	-1.113	-1.110	-1.110	-0.370	0.000	1.850
25/1wo	-14.430	-9.640	-5.180	-4.070	-2.963	-2.960	-2.960	-2.220	-1.850	0.000

Alpha=0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.54110	0.05

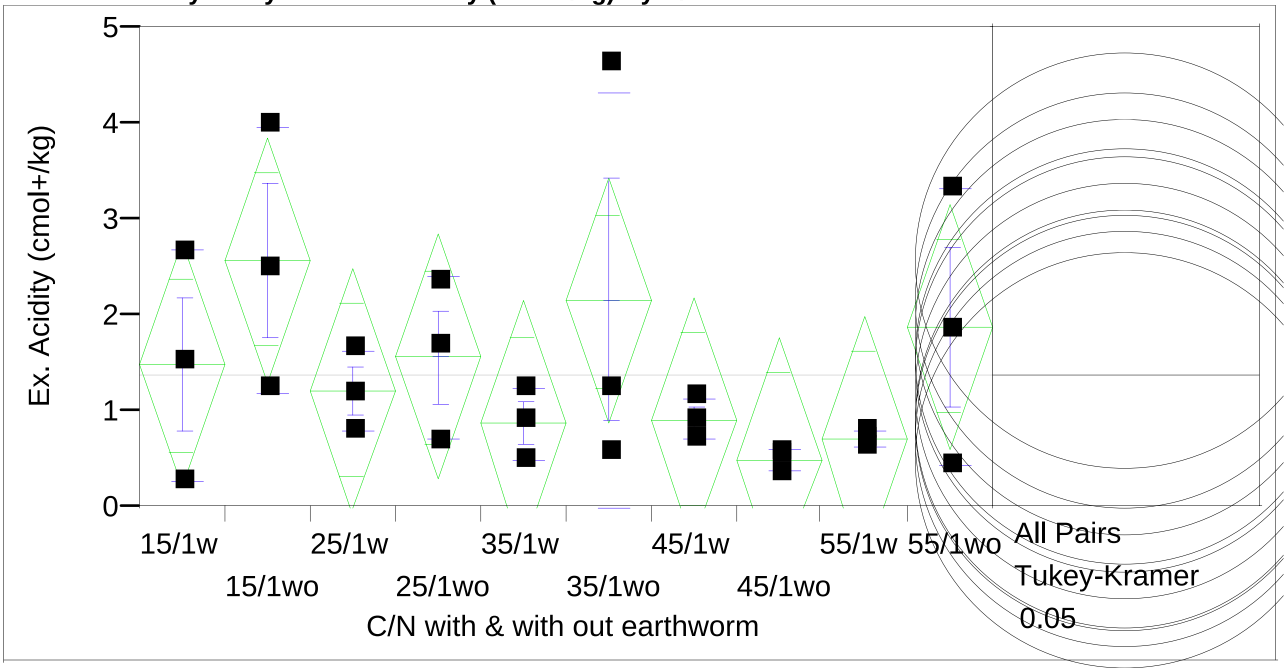
Abs(Dif)-LSD	55/1w	15/1w	45/1w	55/1wo	25/1w	35/1w	15/1wo	35/1wo	45/1wo	25/1wo
55/1w	-18.763	-13.973	-9.513	-8.403	-7.296	-7.293	-7.293	-6.553	-6.183	-4.333
15/1w	-13.973	-18.763	-14.303	-13.193	-12.086	-12.083	-12.083	-11.343	-10.973	-9.123
45/1w	-9.513	-14.303	-18.763	-17.653	-16.546	-16.543	-16.543	-15.803	-15.433	-13.583
55/1wo	-8.403	-13.193	-17.653	-18.763	-17.656	-17.653	-17.653	-16.913	-16.543	-14.693
25/1w	-7.296	-12.086	-16.546	-17.656	-18.763	-18.759	-18.759	-18.019	-17.649	-15.799
35/1w	-7.293	-12.083	-16.543	-17.653	-18.759	-18.763	-18.763	-18.023	-17.653	-15.803
15/1wo	-7.293	-12.083	-16.543	-17.653	-18.759	-18.763	-18.763	-18.023	-17.653	-15.803
35/1wo	-6.553	-11.343	-15.803	-16.913	-18.019	-18.023	-18.023	-18.763	-18.393	-16.543
45/1wo	-6.183	-10.973	-15.433	-16.543	-17.649	-17.653	-17.653	-18.393	-18.763	-16.913
25/1wo	-4.333	-9.123	-13.583	-14.693	-15.799	-15.803	-15.803	-16.543	-16.913	-18.763

Positive values show pairs of means that are significantly different.

Level		Mean
55/1w	A	22.200000
15/1w	A	17.410000
45/1w	A	12.950000
55/1wo	A	11.840000
25/1w	A	10.733333
35/1w	A	10.730000
15/1wo	A	10.730000
35/1wo	A	9.990000
45/1wo	A	9.620000
25/1wo	A	7.770000

Levels not connected by same letter are significantly different

Table 9. Oneway Analysis of Ex. Acidity (cmol+/kg) By C/N with & with out earthworm



Oneway Anova

Summary of Fit

Rsquare	0.350503
Adj Rsquare	0.05823
Root Mean Square Error	1.06019
Mean of Response	1.384
Observations (or Sum Wgts)	30

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C/N with & with out earthworm	9	12.131453	1.34794	1.1992	0.3482
Error	20	22.480067	1.12400		
C. Total	29	34.611520			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15/1w	3	1.47667	0.61210	0.200	2.7535
15/1wo	3	2.57333	0.61210	1.297	3.8502
25/1w	3	1.21000	0.61210	-0.067	2.4868
25/1wo	3	1.56667	0.61210	0.290	2.8435
35/1w	3	0.87333	0.61210	-0.403	2.1502
35/1wo	3	2.14667	0.61210	0.870	3.4235
45/1w	3	0.91667	0.61210	-0.360	2.1935
45/1wo	3	0.49000	0.61210	-0.787	1.7668
55/1w	3	0.71000	0.61210	-0.567	1.9868
55/1wo	3	1.87667	0.61210	0.600	3.1535

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
15/1w	3	1.47667	1.20035	0.6930	-1.505	4.4585
15/1wo	3	2.57333	1.38237	0.7981	-0.861	6.0073
25/1w	3	1.21000	0.42036	0.2427	0.166	2.2542
25/1wo	3	1.56667	0.84571	0.4883	-0.534	3.6675
35/1w	3	0.87333	0.37528	0.2167	-0.059	1.8056
35/1wo	3	2.14667	2.16724	1.2513	-3.237	7.5304
45/1w	3	0.91667	0.22121	0.1277	0.367	1.4662
45/1wo	3	0.49000	0.11533	0.0666	0.204	0.7765
55/1w	3	0.71000	0.09000	0.0520	0.486	0.9336
55/1wo	3	1.87667	1.44507	0.8343	-1.713	5.4664

Means Comparisons

Dif=Mean[i]-Mean[j]	15/1wo	35/1wo	55/1wo	25/1wo	15/1w	25/1w	45/1w	35/1w	55/1w	45/1wo
15/1wo	0.0000	0.4267	0.6967	1.0067	1.0967	1.3633	1.6567	1.7000	1.8633	2.0833
35/1wo	-0.4267	0.0000	0.2700	0.5800	0.6700	0.9367	1.2300	1.2733	1.4367	1.6567
55/1wo	-0.6967	-0.2700	0.0000	0.3100	0.4000	0.6667	0.9600	1.0033	1.1667	1.3867
25/1wo	-1.0067	-0.5800	-0.3100	0.0000	0.0900	0.3567	0.6500	0.6933	0.8567	1.0767
15/1w	-1.0967	-0.6700	-0.4000	-0.0900	0.0000	0.2667	0.5600	0.6033	0.7667	0.9867
25/1w	-1.3633	-0.9367	-0.6667	-0.3567	-0.2667	0.0000	0.2933	0.3367	0.5000	0.7200
45/1w	-1.6567	-1.2300	-0.9600	-0.6500	-0.5600	-0.2933	0.0000	0.0433	0.2067	0.4267
35/1w	-1.7000	-1.2733	-1.0033	-0.6933	-0.6033	-0.3367	-0.0433	0.0000	0.1633	0.3833
55/1w	-1.8633	-1.4367	-1.1667	-0.8567	-0.7667	-0.5000	-0.2067	-0.1633	0.0000	0.2200
45/1wo	-2.0833	-1.6567	-1.3867	-1.0767	-0.9867	-0.7200	-0.4267	-0.3833	-0.2200	0.0000

Alpha=0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.54110	0.05

Abs(Dif)-LSD	15/1wo	35/1wo	55/1wo	25/1wo	15/1w	25/1w	45/1w	35/1w	55/1w	45/1wo
15/1wo	-3.0653	-2.6387	-2.3687	-2.0587	-1.9687	-1.7020	-1.4087	-1.3653	-1.2020	-0.9820
35/1wo	-2.6387	-3.0653	-2.7953	-2.4853	-2.3953	-2.1287	-1.8353	-1.7920	-1.6287	-1.4087
55/1wo	-2.3687	-2.7953	-3.0653	-2.7553	-2.6653	-2.3987	-2.1053	-2.0620	-1.8987	-1.6787
25/1wo	-2.0587	-2.4853	-2.7553	-3.0653	-2.9753	-2.7087	-2.4153	-2.3720	-2.2087	-1.9887
15/1w	-1.9687	-2.3953	-2.6653	-2.9753	-3.0653	-2.7987	-2.5053	-2.4620	-2.2987	-2.0787
25/1w	-1.7020	-2.1287	-2.3987	-2.7087	-2.7987	-3.0653	-2.7720	-2.7287	-2.5653	-2.3453
45/1w	-1.4087	-1.8353	-2.1053	-2.4153	-2.5053	-2.7720	-3.0653	-3.0220	-2.8587	-2.6387
35/1w	-1.3653	-1.7920	-2.0620	-2.3720	-2.4620	-2.7287	-3.0220	-3.0653	-2.9020	-2.6820
55/1w	-1.2020	-1.6287	-1.8987	-2.2087	-2.2987	-2.5653	-2.8587	-2.9020	-3.0653	-2.8453
45/1wo	-0.9820	-1.4087	-1.6787	-1.9887	-2.0787	-2.3453	-2.6387	-2.6820	-2.8453	-3.0653

Positive values show pairs of means that are significantly different.

Level		Mean
15/1wo	A	2.5733333
35/1wo	A	2.1466667
55/1wo	A	1.8766667
25/1wo	A	1.5666667
15/1w	A	1.4766667
25/1w	A	1.2100000
45/1w	A	0.9166667
35/1w	A	0.8733333
55/1w	A	0.7100000
45/1wo	A	0.4900000

Levels not connected by same letter are significantly different

5: Summary of number of Earthworm found in the Bins.

C/N ratio	Number of *Eisenia foetida*				
	Adults		Juveniles		Total
	Initial	After 70 days	Initial	After 70 days	
15/1w*	60	0	0	0	0
25/1w*	60	830	0	1360	2190
35/1w*	60	220	0	430	650
45/1w*	60	330	0	580	910
55/1w*	60	380	0	640	1020

w* = with earthworm